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ABSTRACT

This curriculum guide is designed to build upon the skills and knowledge of industrial electronics gained by the student through the learning activities of the introductory volumes of the electronics program. Specifically, the student, whether in secondary, postsecondary, or adult education, will have the opportunity to expand those skills in three important industrial applications--power control, maintenance planning, and troubleshooting. The curriculum guide includes nine instructional units that cover the following topics: (Section A) direct current controllers, alternating current controllers, power factor regulation, digital counting and metering circuits, analog control, analog control circuits, digital control and maintenance; and (Section B) troubleshooting and troubleshooting power supplies. The guide follows a standard format that includes eight basic components that form each unit of instruction: performance objectives, suggested activities for the teacher, information sheets, assignment sheets, job sheets, transparency masters, and supplements, tests, and answers to tests and assignment sheets. Depending on the specific objectives, there may or may not be transparency masters, supplements, assignment sheets, or job sheets included in the unit of instruction. (KC)

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Applied Industrial Electronics

Power Control and Electronic Troubleshooting

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POWER CONTROL and ELECTRONIC TROUBLESHOOTING

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FOREWORD

In Oklahoma, vocational educators have a basic belief that quality vocational programs require the use of sound instructional materials. A comprehensive approach with a quality treatment served as the primary objective when the Oklahoma State Department of Vocational and Technical Education, Curriculum and Instructional Materials Center began development of educational products for industrial technology. Materials now exist for several specialty fields, including pneumatics, hydraulics, industrial electricity, and industrial electronics. This volume, *Applied Industrial Electronics: Power Control and Electronic Troubleshooting*, supplements *Introduction to Industrial Electricity-Electronics* and *General Industrial Electronics*. For students interested in the industrial electronics field, further study is provided in *Applied Industrial Electronics: Sensors and Logic Systems*.

Industry representatives, educators, and technical specialists collaborated closely to produce these materials in the hope that students will gain the knowledge and skills required in industrial electronics through practical learning experiences. Coupled with the instructor's own methods and expertise, these materials should prove to be a valuable asset for an industrial electronics program.

It is our sincere wish that the manuals in this series will contribute to the development of a competent, safety-conscious work force in the industrial electronics trade.

Dr. Francis Tuttle, Director
Oklahoma State Department of
Vocational and Technical Education

Ivan Armstrong, State Supervisor
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Oklahoma State Department of
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PREFACE

The purpose of *Applied Industrial Electronics: Power Control and Electronic Troubleshooting* is to build upon the skills and knowledge of industrial electronics gained by the student through the learning activities in the introductory volumes of this program. Specifically, the student will have the opportunity to expand those skills in three important industrial applications—power control, maintenance planning, and troubleshooting.

These curriculum materials have been designed for use in full-time secondary and post-secondary classes, as well as part-time adult classes. The material is easily adaptable to open-entry, open-exit programs to allow students to progress at their individual paces.

A skilled instructor will be able to supplement, personalize, and localize this material to meet specific training needs. The design of the material allows the different topics to be presented in a variety of sequences, and even permits the use of part of a unit of instruction at a given time. The "Use of this Publication" section will greatly aid the instructor and student in getting the most from these materials.

Bob Patton, Coordinator
Curriculum and Instructional
Materials Center
Oklahoma State Department of
Vocational and Technical Education

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ACKNOWLEDGEMENTS

Any project as comprehensive and involved as this guideline for teaching industrial electronics requires the contributions of a great number of people. We are thankful for the tremendous support we have received in the development of this book. First, we are grateful to the Oklahoma State Department of Vocational and Technical Education under the direction of Dr. Francis Tuttle, and especially to the industrial technology advisory committee for recognizing the need for these instructional materials.

We worked closely with the CIMC staff, who trained us and guided us during the writing process. The primary review committee consisted of several qualified instructors and industrial experts whose contributions were invaluable. The committee included

Wallace Farris
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Bartlesville, Oklahoma

Raymond S. Todish
Maintenance Foreman
Mercury Marine
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Cecil Hendrick
Maintenance General Foreman
National Standard Company
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Jim Wilson
Assistant Superintendent of Adult
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After the writing was completed, several vocational training programs field-tested these materials. Instructors involved in the field-test then met to review the results and suggest revisions. The final draft of these materials owes much to these instructors and industry people who took the time and showed the patience to use the field-test copy of this manual. The committee that reviewed the field-test results included

Charles Herndon
Electronics Instructor
Tulsa County Area Vo-Tech School
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Stan Rosen
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Drumright, Oklahoma

B.E. Carney
Industrial Maintenance Instructor
Kiamichi Area Vo-Tech School
Idabel, Oklahoma

We owe a great deal of gratitude to the many people involved in the production process. Robert Hilley served as the project coordinator during the production phase of this project at the CIMC. The various drafts of the manuscript were ably produced by the phototypesetters in the Communication Center under the direction of Debbie Hixson. Special thanks to Stephanie Shipley and Lisa Tomlinson.

The Art Department, under Bob Davis, provided the excellent illustrations and graphics that accompany the text. We are grateful especially to Gary Bradley who did the majority of the artwork. The quality of the published product is the result of the care and talents of the Print Shop personnel under the supervision of Noel Wilcoxson. To these and many others, we are extremely grateful because this book would not be possible without the combined efforts of everyone involved.

It is our sincere wish that these materials be of value to instructors in industrial electronics programs and that they benefit those students who are pursuing careers in this vital and rewarding field.

Rick Morrow

John Humler

USE OF THIS PUBLICATION

Instructional Units

Applied Industrial Electronics: Power Control and Electronic Troubleshooting includes nine instructional units. A standard format was established in 1970 for development of instructional materials for all Oklahoma vocational teachers. This format includes eight basic components that form a unit of instruction: performance objectives, suggested activities for the teacher, information sheets, assignment sheets, job sheets, transparency masters and supplements, tests, and answers to tests and assignment sheets. Depending on the specific objectives, there may or may not be transparency masters, supplements, assignment sheets, or job sheets included in the unit of instruction.

All of the unit components "zero in" on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help him or her determine the following

A. Amount of material that can be covered in each class period
B. Skills that must be demonstrated
    1. Supplies and equipment needed
    2. Amount of practice needed
    3. Amount of class time needed for demonstrations
C. Supplementary materials, such as pamphlets and filmstrips, that must be ordered
D. Resource people to contact

Performance Objectives (white pages)

Each unit of instruction is based on the performance needed for successful employment in an occupational area. Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching/learning process, it is important that teachers and students have a common understanding of the intent of the objectives. Following is a list of performance terms, their meanings, and behavioral synonyms that may have been used in this material.

A. Name — The individual supplies a name for objects, events, or people

Behavioral synonyms: Label, list, letter, record, reiterate, repeat, write

B. Identify — The individual selects a named, described, or pictured object by pointing to it, touching it, picking it up, or selecting it

Behavioral synonyms: Select, mark, match, choose, judge

C. State a rule — The individual communicates a relationship or principle that could be used to solve problems or perform a task

D. Apply a rule — The individual supplies an answer to a problem by using a stated relationship or principle

Behavioral synonyms: Solve, calculate

E. Describe — The individual relates sufficient characteristics or properties of an object or event so that a second individual will be able to state what is being discussed

Behavioral synonyms: Define, discuss, interpret, recite, tell how, tell what happens when

F. Distinguish — The individual selects an object or event from two or more that are easily confused

Behavioral synonyms: Discriminate, differentiate

G. Order — The individual arranges three or more objects or events in a sequence based on a stated property

Behavioral synonyms: Arrange, sequence, list in order, classify, divide, isolate, sort

H. Construct — The individual makes a physical object, a verbal statement, or a drawing

(NOTE: *Construct* is used when the finished product or result is important.)

Behavioral synonyms: Draw, make, build, design, formulate, reproduce, transcribe, convert, put together, compile

I. Demonstrate — The individual performs several operations necessary to carry out a specified process

(NOTE: *Demonstrate* is used when it is desirable to watch the student perform a task, one of the highest levels of student performance.)

Behavioral synonyms: Show your work, show procedure, perform an experiment, perform the steps, operate, remove, replace, turn off/on, (dis)assemble, (dis)connect

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Prepare for each unit by deciding how each objective can best be taught.

The objective sheet may also be used as a quick pretest to determine prior knowledge of students and to determine whether further study or activities are necessary. Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When changes in objectives are made, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested Activities and Supplements (pink pages)

This component is included only in teacher material. The suggested activities page assists teachers during the preparation stage of the teaching/learning process by providing suggestions for delivery and/or presentation during the instructional process. Read the suggested activities before teaching the units to allow time to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

The references that are listed are ones used in the development of each unit. They should be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or occupational objectives in the area covered.

Information Sheet (green pages)

The information sheet provides "must know" content essential for meeting the cognitive (knowledge level) objectives of the unit. The information is written in a topical outline form and is keyed to the specific objectives.

Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. The information sheet may also be used for coordination activities and advisory committees.

Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide motivation for each unit.

Transparency Masters (white pages in teacher material and green in student material)

Transparency masters provide information in a special way. Transparencies direct the class's attention to the topic of discussion. Transparencies may present new information, or they may reinforce information presented in the information sheet. They are particularly effective when identification is necessary. Make transparencies and place them in the notebook where they will be immediately available for use.

Assignment Sheets (brown pages)

Assignment sheets give students a chance at problem solving, self-assessment, and/or practical experience. They assist students in the application of knowledges that are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided when appropriate and can be used by the student and/or teacher for checking student progress.

Job Sheets (blue pages)

Job sheets are another important segment of a unit of instruction. The job sheets provide a list of equipment, tools, and materials needed to complete a manipulative or psychomotor skill. They describe a step-by-step procedure needed to complete each task or job. Diagrams, photographs, and illustrations are provided to assist students in achieving the skill.

Instruments in job sheets are not in order of use. The order of use should be taught in the classroom. In this way, students will not depend entirely on job sheets for instrument setup.

The teacher should demonstrate to students the procedures outlined in each job sheet. Furthermore, the teacher needs to localize the job sheet according to the equipment and supplies available in the local lab or shop situation. Job sheets also furnish potential employers with a picture of the skills being taught and the performances they might reasonably expect from a person who has had this vocational instruction.

Tests (yellow pages)

This component provides criterion-referenced evaluation of every objective listed in the unit of instruction. It is crucial to note that both paper/pencil and performance objectives must be evaluated.

The tests may be written or oral. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of questions from the units covered may be used for final tests at the end of each term if desired. If objectives have been added, deleted, or modified, be sure to make the changes on the test.

The acceptable response on a unit test, 85 percent in most units, may be raised or lowered to fit the topic or students' ability levels. The percentage applies to the overall score, not to each question. The final unit grade should be obtained by using the paper/pencil score and evaluations of student demonstrations of the desired skills.

Answers to Test and Assignment Sheets (pink pages)

These components are designed to assist the teacher in evaluation of student performances.

Page Numbering

Each publication from the Curriculum and Instructional Materials Center is assigned a specific abbreviation. For example, *Applied Industrial Electronics: Power Control and Electronic Troubleshooting* has been abbreviated PCT. The units are then numbered consecutively within each section. An example of a page number is PCT-1-A. Since CIMC publications are loose leaf, this system of page numbering was adopted so that pages from different manuals would not get mixed up.

Methods of Disseminating Material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder for the units. This is convenient for taking the materials home to study. Upon completion, each unit is then placed in a larger binder. The large binders may be purchased at cost from the CIMC. Some teachers store the materials by units in filing cabinets or boxes until needed. All the units may be given out at once if desired.

For best results, provide student materials for each student. Student materials contain everything but the test answers, answers to assignment sheets, and suggested activities. All tests are collated at the back of student material and should be removed and stored until needed.

Teaching Methods

It is a challenge to keep students motivated. Supplement the objectives by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each objective can best be taught. Allow students to become involved in preparing and planning.

Competency Profiles

Competency profiles are folders used to document student performance. The profile contains a list of the specific job competencies that should be achieved prior to leaving the training program.

CORRECTIONS AND SUGGESTIONS

The Curriculum and Instructional Materials Center (CIMC) wants to provide vocational instructors and students with materials that are accurate and effective. Although the Center strives to maintain the highest standards of development and production, oversights occasionally do occur. If you find any errors in this or other CIMC publications, or have suggestions for improving their usefulness in vocational programs, please notify the CIMC staff. One easy way of pointing out errors is to make a photocopy of the affected page and to indicate the correction on the copy. You can then mail the information to the CIMC, where it will be used to correct the publication before the materials are reprinted.

To ensure that the material is updated on a timely basis, it is important that you notify the Center of necessary corrections as soon as possible after discovering the error. Do not assume that someone else will notice the error and inform the CIMC; other users may be making the same assumption. Please send corrections and recommendations for improving this publication to the following address:

Manager of Development
Curriculum and Instructional Materials Center
Oklahoma State Department of Vocational and
Technical Education
1500 West Seventh Avenue
Stillwater, Oklahoma 74074

DC CONTROLLERS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to analyze the output of and troubleshoot a DC controller. The student will show this knowledge by completing assignment sheet, job sheet, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with DC controllers to their correct definitions.
2. State meanings of abbreviations and acronyms associated with DC controllers.
3. Identify circuit symbols associated with DC controllers.
4. List industrial applications for DC controllers.
5. Label components of a DC controller.
6. Describe SCR gating control and its results.
7. Select from a list characteristics of synchronized thyristor timing.
8. Demonstrate the ability to construct a DC controller and analyze output.

DC CONTROLLERS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheet.

   C. Provide students with information, assignment, and job sheets.

   D. Discuss unit and specific objectives.

   E. Discuss information and assignment sheets.

   F. Demonstrate and discuss procedures outlined in job sheets.

   G. Connect a DC controller to a small motor with voltage and current meters on the motor leads. Load the motor to illustrate the relationship between voltage, current, load, and RPM for a DC motor.

   H. Tour a manufacturing plant that utilizes DC controllers for the various applications listed and point out that equipment to the students.

   I. Give test.

   J. Reteach, if necessary.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency master #1 — Synchronized SCR Gate Firing Waveforms

   E. Assignment Sheet #1 — Label Components on a Schematic of a DC Controller

   F. Answers to assignment sheet

   G. Test

   H. Answers to test

SUGGESTED ACTIVITIES

III. Unit references

- A. Wilson, Jerry. *Handbook of DC Drive System*. Marketing Training Department, Reliance Electric Company. (Cleveland, Ohio: Reliance Electric Company, n.d.)
- B. "Industrial Motor Control." (Chicago: Energy Concepts, Inc., 1979).

DC CONTROLLERS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. DC controller — Variable DC power supply used to control power to motors, welders, etc.

B. Inverter — Electrical device that transforms DC to AC

(NOTE: When referring to amplifiers, the term *inverter* is interpreted as an inverting amplifier. In power circuits, the definition above applies.)

C. Rectifier — Electrical device that transforms AC to pulsating DC

D. Armature — Part of motor or generator that is usually the rotating element

E. Field — Coil of wire used to supply an electromagnetic field; usually stationary

F. Stator — Stationary part of a motor or generator; usually the field

G. Rotor — Rotating part of a motor or generator; usually the armature

H. Winding — Coil of wire

I. Bus — Common conductor that supplies several inputs or outputs

J. Counter EMF — Electromotive force that opposes changes in the supply power; developed as a result of expanding or collapsing an electromagnetic field

(NOTE: Electromagnets, transformers, inductors, and motor windings all produce counter EMF, which is also called *back EMF*.)

K. Trigger pulse generator — Circuit that develops gating pulses

L. Jog — To rotate a motor in fractions of a revolution to obtain a particular position

M. Plugging — Braking a motor by reversing the supply voltage or, in the case of three-phase, reversing two phase connections

N. Dynamic braking — Method of slowing a DC motor by forcing it to behave as a heavily loaded generator through a resistor

O. Duty cycle — Conduction time of an SCR expressed as a percentage of time of any full cycle

INFORMATION SHEET

II. Abbreviations and acronyms

A. A, ARM — Armature

B. F, FLD — Field

C. L — Line, inductor

D. NC — Numerical control

(NOTE: Compare to *N.C.)*

E. S — Series

F. EMF — Electromotive force

G. SCR — Silicon controlled rectifier

H. D, CRX — Rectifier

I. SUS — Silicon unilateral switch

J. CNC — Computer numerical control

K. AP — Antiplugging relay

L. CR — Control relay

M. Op amp — Operational amplifier

N. H — Transformer primary lead designator

O. X — Transformer secondary lead designator

P. N.O. — Normally open

Q. N.C. — Normally closed, not connected

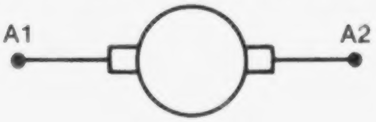
R. TD — Time delay

III. Circuit symbols (Figures 1-16)

A. DC Motors

1. Permanent magnet (no field coil shown)

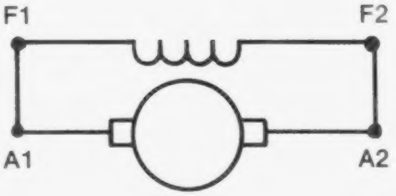
FIGURE 1



INFORMATION SHEET

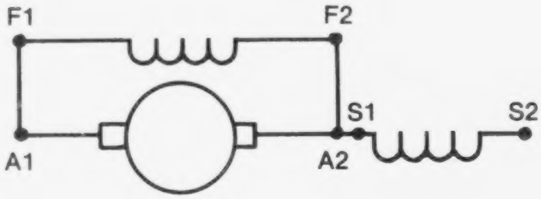
2. Shunt field

FIGURE 2



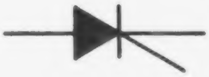
3. Compound windings

FIGURE 3


F1
F2
S1
S2
A1
A2

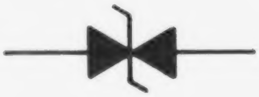
B. Thyristor (SCR)

FIGURE 4



C. Thyrector

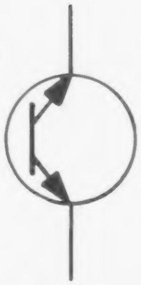
FIGURE 5



INFORMATION SHEET

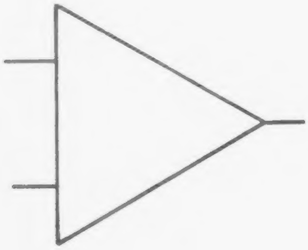
D. Diac

FIGURE 6



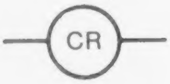
E. Operational amplifier

FIGURE 7



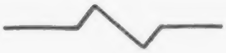
F. Relay coils

FIGURE 8



Shunt

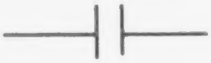
FIGURE 9



Series

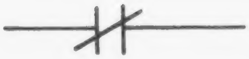
G. Relay contacts

FIGURE 10



(Normally open)

FIGURE 11

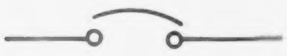


(Normally closed)

INFORMATION SHEET

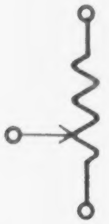
H. Circuit breaker

FIGURE 12



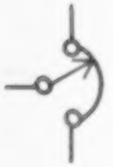
I. Potentiometer

FIGURE 13



(Conventional)

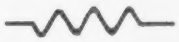
FIGURE 14



(Alternate)

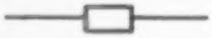
J. Resistor

FIGURE 15



(Conventional)

FIGURE 16



(Alternate)

IV. Industrial applications of DC controllers

A. DC motor speed control

EXAMPLES: Machinery drive motors, CNC machine drives, conveyor drives

B. DC welding power supplies

EXAMPLES: Resistance welding, TIG, MIG, stick welders

INFORMATION SHEET

V. DC Controller components (Figure 17)

A. Filter capacitor

B. Full-wave bridge rectifier

C. Zener diodes

D. Thyrector

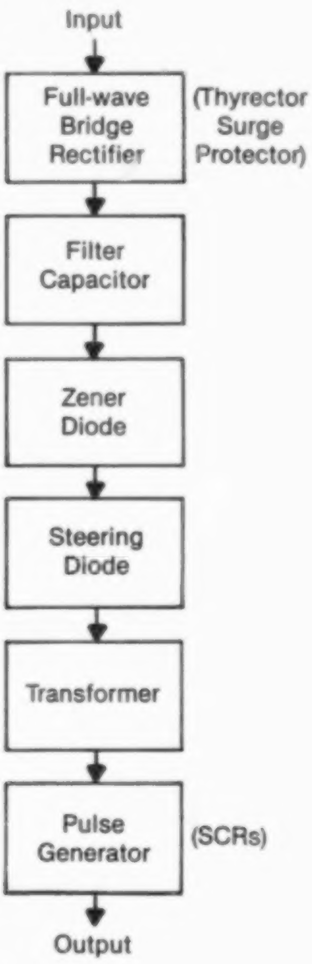
E. Transformer

F. SCRs

G. Pulse generator

H. Steering diode

FIGURE 17


Input
Full-wave Bridge Rectifier
(Thyrector Surge Protector)
Filter Capacitor
Zener Diode
Steering Diode
Transformer
Pulse Generator
(SCRs)
Output

INFORMATION SHEET

VI. Results of SCR gating to control power

   A. SCR — Firing occurs when the proper gate trigger is applied during an AC half-cycle; switches off automatically when the voltage reverses during AC transition

   B. SCR rectified output (waveform D) — Is chopped according to gate timing

   C. Filtered DC (waveform E) — Will exhibit amplitude in proportion to the amount of AC gated through the SCRs

   EXAMPLE: Waveform D contains approximately 80% of the power of waveform A due to the delay in gating the SCRs

   (NOTE: Technicians should understand the difference between the action of a rheostat and that of a SCR. A rheostat continues to use power, while an SCR switches off power.)

VII. Characteristics of synchronized thyristor timing (Transparency #1)

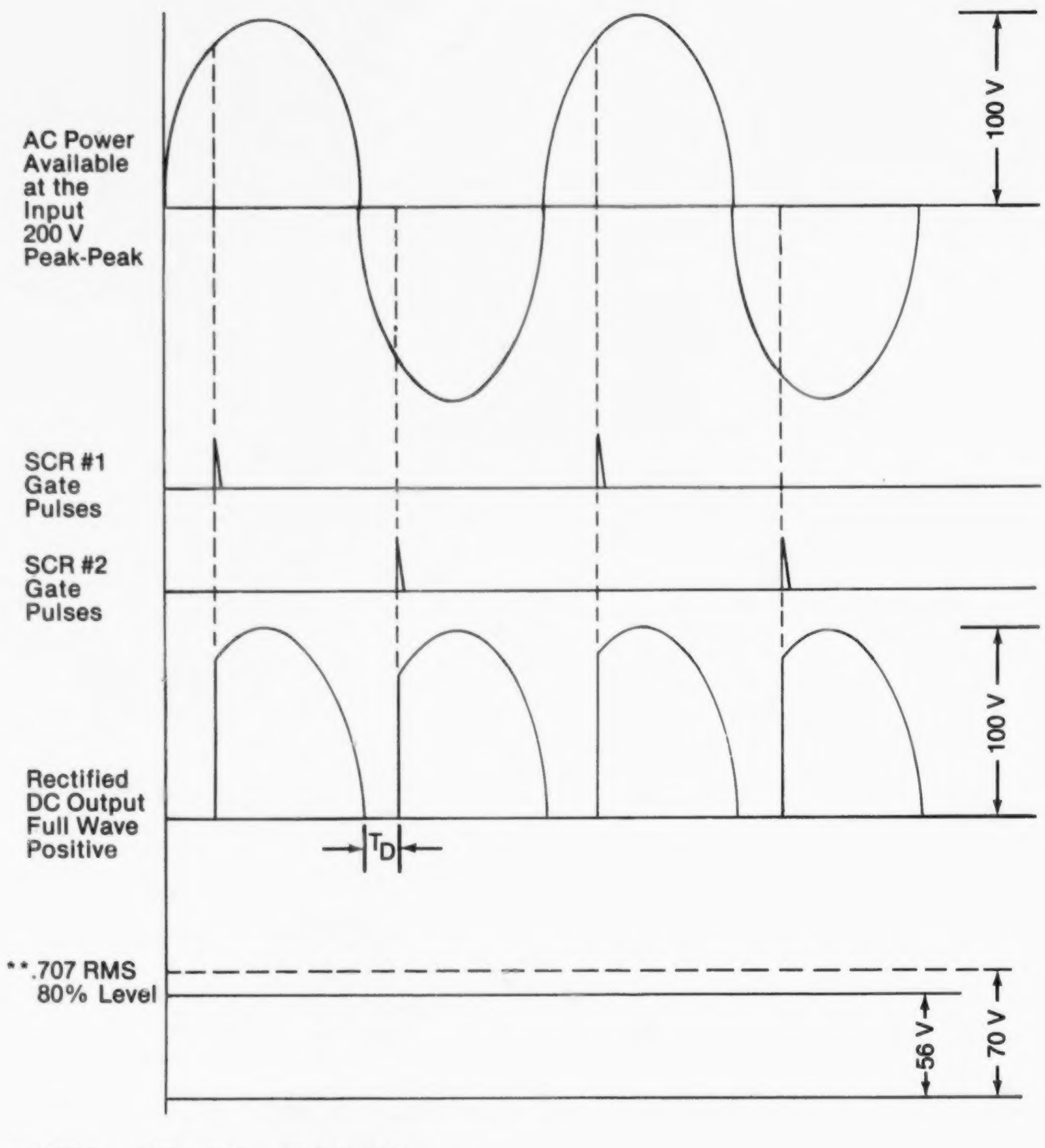
   A. Output waves are uniform

   B. Ripple is constant at a constant output level

   C. Circuitry must be triggered from input power frequency

   D. Delay is varied to control power out

Synchronized SCR Gate Firing Waveforms


AC Power
Available
at the
Input
200 V
Peak-Peak
100 V
SCR #1
Gate
Pulses
SCR #2
Gate
Pulses
Rectified
DC Output
Full Wave
Positive
100 V
T_D
**.707 RMS
80% Level
56 V
70 V

**NOTE: .707 × 100 = 70.7 V RMS
80% × 70 = 56 V

DC CONTROLLERS
UNIT I

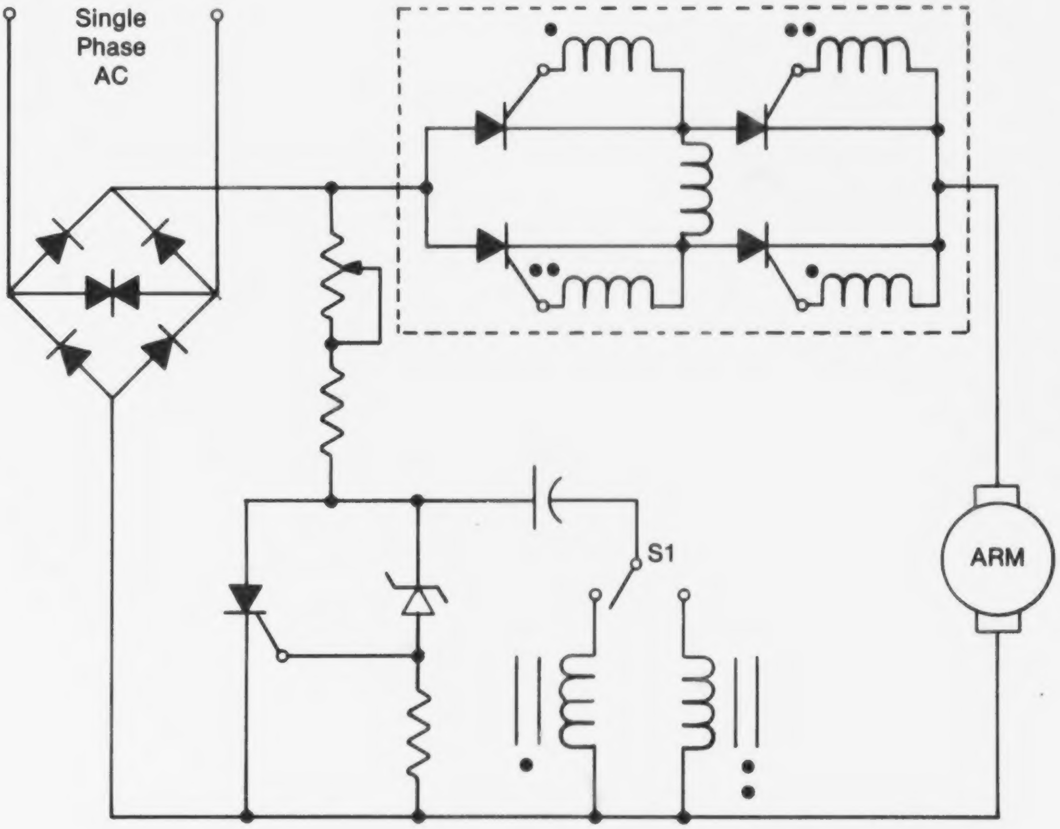
ASSIGNMENT SHEET #1 — LABEL COMPONENTS ON A SCHEMATIC OF A DC CONTROLLER

NAME ______________________________ SCORE ______________

In order to analyze the design requirements of a DC controller to determine how it should operate, a technician must know how to read schematics and interpret circuitry. One of the keys to understanding the functioning of a DC controller is the ability to recognize the basic components of the system and their role in the circuitry. Study the schematic below and label the components listed. Write the number beside the component next to the component's location on the schematic.

(NOTE: Some components may be used more than once.)

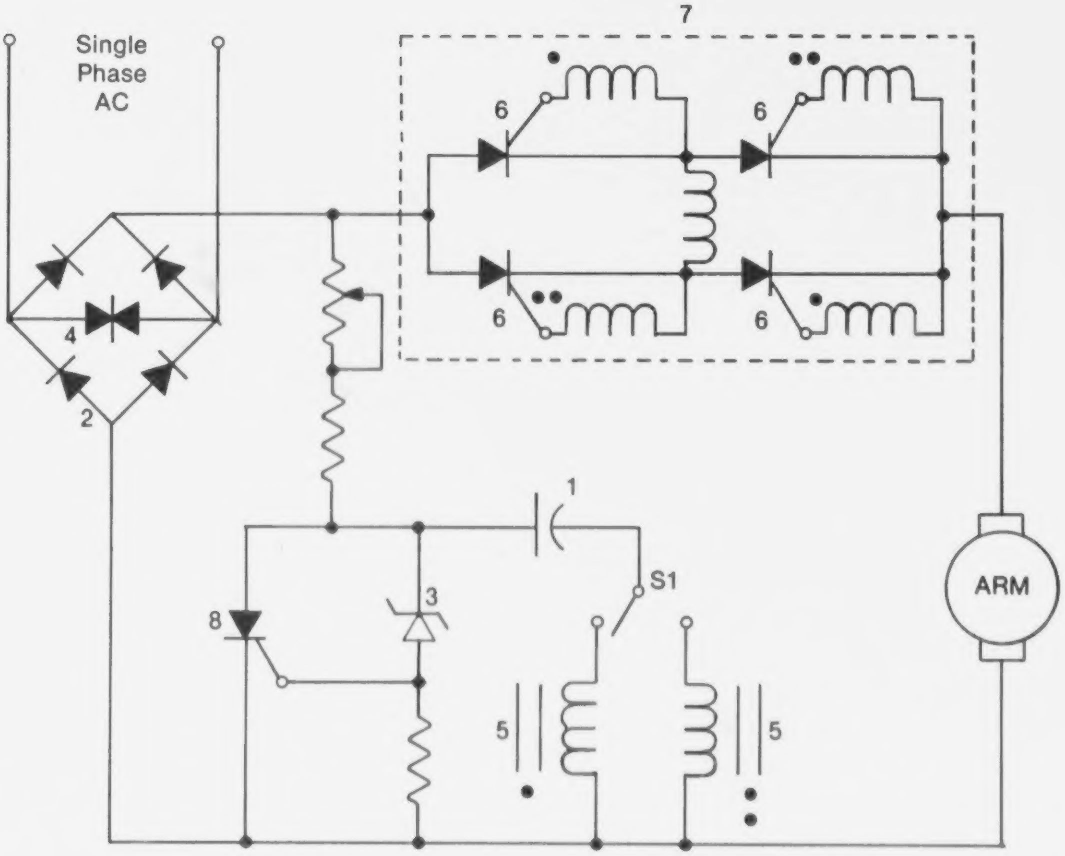
1. Filter capacitor
2. Full-wave bridge rectifier
3. Zener diode
4. Thyrector
5. Transformer
6. SCR
7. Pulse generator
8. Steering diode



DC CONTROLLERS
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1


7
Single Phase AC
6
6
6
6
4
2
1
S1
3
8
5
5
ARM

DC CONTROLLERS
UNIT I

JOB SHEET #1 — CONSTRUCT A DC CONTROLLER AND ANALYZE OUTPUT

I. Tools and materials

- A. DC motor controller, solid-state circuit with thyristors, Reliance Flexpak variable-speed drive, or similar devices
- B. Oscilloscope, dual trace, with two probes
- C. DC motor matched to DC controller being used
- D. Tachometer, hand-held or strobe-type
- E. Multimeter
- F. Schematic diagram for controller to be used
- G. Isolation transformer
- H. Ammeter

II. Procedure

- A. Connect the DC controller to the appropriate input power using an isolation transformer
- B. Connect the DC motor to the controller
- C. Ask your instructor to check your work
- D. Turn on and operate the controller to verify that it performs properly, then turn it off
- E. Connect the oscilloscope channel to an SCR gate lead
- F. Connect the other oscilloscope channel to the rectified DC output of the thyristor rectifier circuitry
- G. Connect the multimeter across the DC output leads to the motor
- H. Prepare the tachometer to measure the motor RPM and have your instructor check your work
- I. Turn on the DC controller and oscilloscope
- J. Again verify that the DC controller performs properly and varies the motor speed

JOB SHEET #1

K. Adjust the oscilloscope for a stable dual-trace display of the trigger and output waveforms

L. Observe the trigger pulse timing, motor RPM changes, and DC voltmeter changes

M. Complete the following data table

MOTOR RPM MEASURED BY TACHOMETER	DC VOLTMETER READING TO MOTOR ARMATURE	TIME BETWEEN AC ZERO CROSSING AND SCR FIRING SHOWN ON OSCILLOSCOPE
(NOTE: Continue to motor top RPM or to end of data table.)		

JOB SHEET #1

N. Operate the controls to determine the characteristics of the controller and provide the information requested below

1. What is the slowest RPM the motor will operate at and still rotate smoothly?

   ____

2. What is the maximum RPM of the motor?

   ____

3. Does the meter reading change proportionally to the RPM?

   ____

O. Disconnect multimeter

P. Connect ammeter in series with motor

Q. Read the anmeter and answer the questions below

1. What is the voltage and current at the lowest RPM?

   ____

2. What is the voltage and current at the highest RPM?

   ____

3. Does the ammeter reading change proportionally to the RPM?

   ____

R. Show your results to the instructor

S. Put away tools and materials

DC CONTROLLERS
UNIT I

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with DC controllers to their correct definitions. Write the number of the term beside its correct definition.

______a. Electromotive force that opposes changes in the supply power; developed as a result of expanding or collapsing an electromagnetic field

______b. Conduction time of an SCR expressed as a percentage of time of any full cycle

______c. Stationary part of a motor or generator; usually the field

______d. Method of slowing a DC motor by forcing it to behave as a heavily loaded generator through a resistor

______e. Electrical device that transforms AC to pulating DC

______f. Electrical device that transforms DC to AC

______g. Coil of wire used to supply an electromagnetic field; usually stationary

______h. Braking a motor by reversing the supply voltage or, in the case of three-phase, reversing two phase connections

______i. Part of motor or generator that is usually the rotating element

______j. Variable DC power supply used to control power to motors, welders, etc.

______k. Circuit that develops gating pulses

______l. Rotating part of a motor or generator; usually the armature

______m. To rotate a motor in fractions of a revolution to obtain a particular position

1. Inverter
2. Rectifier
3. Armature
4. Field
5. Stator
6. Rotor
7. Bus
8. Counter EMF
9. Winding
10. Trigger pulse generator
11. Jog
12. Plugging
13. Dynamic braking
14. DC Controller
15. Duty cycle

TEST

_____n. Common conductor that supplies several inputs or outputs

_____o. Coil of wire

2. State meanings of abbreviations and acronyms associated with DC controllers. Write the meaning in the space provided.

a. A, ARM — ____________________

b. F, FLD — ____________________

c. L — ____________________

d. NC — ____________________

e. N.C. — ____________________

f. S — ____________________

g. EMF — ____________________

h. D, CR, X — ____________________

i. SCR — ____________________

j. SUS — ____________________

k. CNC — ____________________

l. AP — ____________________

m. CR — ____________________

n. OP amp — ____________________

o. H — ____________________

p. X — ____________________

q. N.O. — ____________________

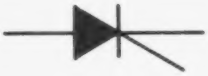
r. TD — ____________________

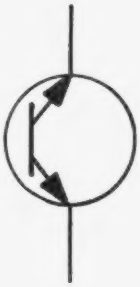
TEST

3. Identify circuit symbols associated with DC controllers. Write the correct name in the space provided.

Permanent magnet DC motor
Shunt field DC motor
Compound winding DC motor
Thyristor (SCR)
Thyrector
Diac
Resistor

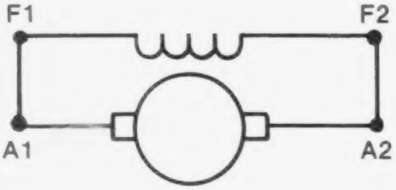
Operational amplifier
Shunt relay coil
Series relay coil
Relay contact
Circuit breaker
Potentiometer

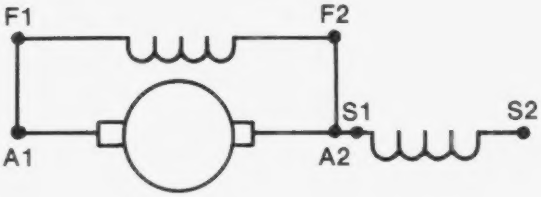




a.______________________________

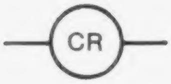
b.______________________________

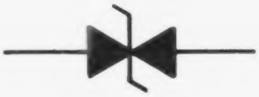




c.______________________________

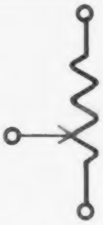
d.______________________________

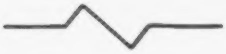




e.______________________________

f.______________________________

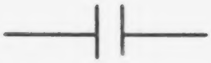


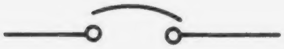


g.______________________________

h.______________________________

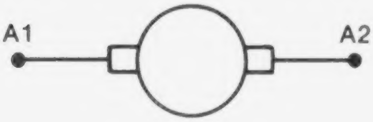
TEST

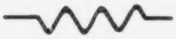




i. ______________________________

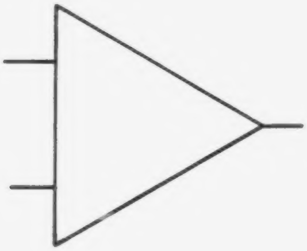
j. ______________________________





k. ______________________________

l. ______________________________



m. ______________________________

4. List two industrial applications of DC controllers.

   a. ____

   b. ____

TEST

5. Label components of a DC controller. Write the correct names in the spaces provided.

6. Describe SCR gating control and its results. Explain how the terms below apply to SCR gating.

   a. SCR firing — ______________________________

   ____

   ____

   b. SCR rectified output — ______________________________

   ____

   ____

   c. Filtered DC — ______________________________

TEST

____

____

7. Select from a list characteristics of synchronized thyristor timing. Write an "X" beside each correct characteristic.

______a. Output waves are uniform

______b. Ripple is constant at a constant output level

______c. Output steadily increases in amplitude

______d. Circuitry must be triggered from input power frequency

______e. Delay is varied to control power out

______f. Produces flat waves at peak power

(NOTE: Test items 8 and 9 are the assignment sheet and the job sheet. If these have not been completed, see your instructor.)

8. Label components on a schematic of a DC controller.

9. Demonstrate the ability to construct a DC controller and analyze output.

DC CONTROLLERS
UNIT I

ANSWERS TO TEST

1. a. 8
   b. 15
   c. 5
   d. 13
   e. 2
   f. 1
   g. 4
   h. 12
   i. 3
   j. 14
   k. 10
   l. 6
   m. 11
   n. 7
   o. 9

2. 1. Armature
   b. Field
   c. Line indicator
   d. Numerical control
   e. Normally closed, not connected
   f. Series
   g. Electromotive force
   h. Silicon controlled rectifier
   i. Rectifier
   j. Silicon unilateral switch
   k. Computer numerical control
   l. Antiplugging relay
   m. Control relay
   n. Operational amplifier
   o. Transformer primary lead designator
   p. Transformer secondary lead designator
   q. Normally open
   r. Time delay

3. a. Thyristor
   b. Diac
   c. DC motor with shunt field
   d. DC motor with compound windings
   e. Shunt relay coil
   f. Thyrector
   g. Potientometer
   h. Series relay coil
   i. Relay contact
   j. Circuit breaker
   k. Permanent magnet motor
   l. Resistor
   m. Operational amplifier

4. a. DC motor speed control
   b. DC welding power supplies

5. a. Filter capacitor
   b. Full-wave bridge rectifier
   c. Zener diode
   d. Thyrector
   e. SCR
   f. Pulse generator
   g. Transformer
   h. Steering diode

ANSWERS TO TEST

6. a. Occurs when the proper gate trigger is applied during an AC half-cycle; switches off automatically when the voltage reverses during AC transition
   b. Is chopped according to gate timing
   c. Will exhibit amplitude in proportion to the amount of AC gated through SCRs.

7. a, b, d, e

8. Evaluated to the satisfaction of the instructor.

9. Performance objective evaluated to the satisfaction of the instructor.

AC CONTROLLERS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and analyze an AC controller. The student will show this ability by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with AC controllers to their correct definitions.
2. Match symbols and abbreviations associated with AC controllers to their correct interpretations.
3. Identify schematic symbols associated with AC controllers.
4. Select from a list statements comparing AC and DC motor control.
5. Identify inverter and converter schematic diagrams.
6. Distinguish among types of AC controllers and their characteristics.
7. Locate misoriented SCRs in schematic diagrams.
8. Analyze SCR inverter schematic diagrams.
9. Demonstrate the ability to construct and analyze an SCR inverter.

AC CONTROLLERS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheet.

   C. Provide students with information, assignment, and job sheets.

   D. Discuss unit and specific objectives.

   E. Discuss information and assignment sheets.

   F. Demonstrate and discuss procedures outlined in job sheets.

   G. Discuss the installation and operation of the AC controller using the instruction manual of the controller and the NEC manual.

   H. Take the students to visit a local industry that utilizes AC controllers or motor variable speed drives.

   I. Review sections of previous units or basic electronic references which discuss multivibrators, UJT oscillators, and SCR circuitry which is incorporated in AC controllers.

   J. Discuss the different characteristics of AC and DC variable speed controller systems such as motor torque and RPM control.

   K. Give test.

   L. Reteach, if necessary.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1 — Power Circuit Terminology

      2. TM #2 — Simplified Block Diagram for an AC Controller

      3. TM #3 — Closed Loop AC Controller Block Diagram

      4. TM #4 — Types of AC Motor Controllers

SUGGESTED ACTIVITIES

E. Assignment Sheet #1 — Analyze SCR Inverter Schematic Diagrams

F. Answer to assignment sheet

G. Job Sheet #1 — Construct and Analyze an SCR Inverter

H. Test

I. Answer to test

III. Unit references

A. Jacouides, Linos J., et al. "A Cycloconverter — Synchronous Motor Drive for Traction Applications," *IEEE Transactions on Industry Applications,* July/August 1981, Vol. 1A-17, No. 4, pp. 407-418.

B. Jarc, Dennis A. and Robechek, John D. "Static Induction Motor Drive Capabilities for the Petroleum Industry," *IEEE Transactions on Industry Applications,* January/February 1982, Vol. 1A-18, pp. 41-45.

C. Maloney, Timothy J. *Industrial Solid-State Electronics,* Prentice-Hall, New Jersey, 1979.

D. Mazda, F. F. *Thyristor Control.* John Wiley & Sons, New York, 1973.

AC CONTROLLERS
UNIT II

INFORMATION SHEET

I. Terms and definitions

   A. AC controller — Device which varies the AC waveform to control an AC load such as a motor

      EXAMPLE: AC controllers may be used to control motors for driving loads, servo motors, control valves, etc.

   B. Inverter — Device which transforms DC to AC

   C. Rectifier — Device which transforms AC to pulsating DC

   D. Frequency converter — Device which transforms AC of one frequency to AC of another frequency

      (NOTE: A frequency converter may change frequencies up or down.)

   E. Servo motor — Motor which operates at precise speeds to position mechanical systems

      EXAMPLES: CNC machining equipment, antenna position, robotics equipment

   F. Pulse width modulation — Method of varying the pulse width to load for variable output control

   G. Closed loop control — Method of output control by sampling output results for comparison with desired results

   H. Variable speed drive — Any of the mechanical, electrical, hydraulic or electronic systems which allow motor speed control

   I. Torque — Force which produces rotation about an axis

      (NOTE: Torque is important to start a load into motion.)

   J. Sinusoidal — Resembling a sine wave or sine function

INFORMATION SHEET

II. Symbols and abbreviations

A. Φ — Phase

B. Hz — Hertz

C. PWM — Pulse width modulation

D. CNC — Computer numerical control

E. SCR — Silicon controlled rectifier

F. SUS — Silicon unilateral switch

G. D, CRX — Crystal rectifier

H. A, B, C — Three phases of AC 3Φ power

I. VCO — Voltage controlled oscillator

J. Σ — Summing circuit

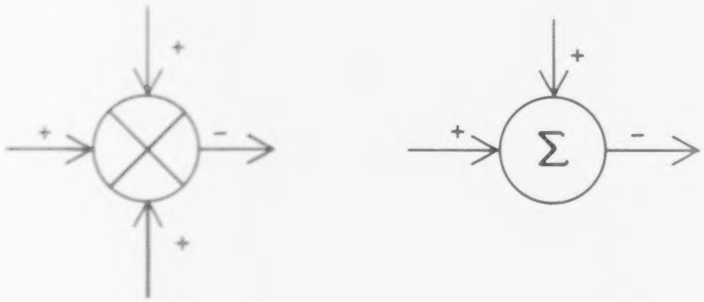
K. VFO — Variable frequency oscillator

L. PMG — Permanent magnet generator (tachometer)

III. Schematic symbols (Figures 1-7)

A. Summing circuit (or point)

FIGURE 1

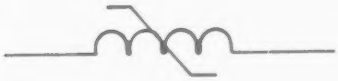


(NOTE: A summing circuit may have more than two inputs which may be of either polarity. Symbols vary among designers.)

INFORMATION SHEET

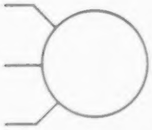
B. Saturable core reactor

FIGURE 2



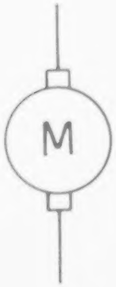
C. AC motor

FIGURE 3



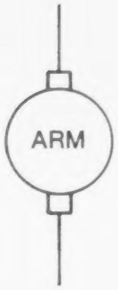
D. DC motor

FIGURE 4



INFORMATION SHEET

FIGURE 5

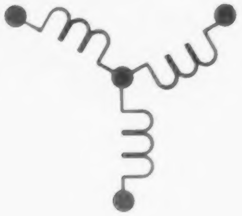


(NOTE: DC motors are often drawn simply as circles with wiring connections. They can be distinguished from instruments or meters only by the abbreviation inside the circle. The same symbol without an abbreviation is used to represent a coil. Motors or generators represented this way may be numbered within the symbol, such as M1, M2, etc. Field symbols are often connected to motor symbols with the number of loops in the field identifying its type. A shunt field is shown with four loops, a series field is represented by three loops, while a commutated or compensated field is indicated with a two-loop field.)

INFORMATION SHEET

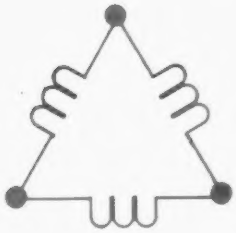
E. Wye transformer or winding arrangement

FIGURE 6



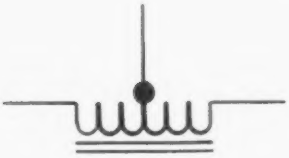
F. Delta transformer or winding arrangement

FIGURE 7



G. Auto transformer

FIGURE 8



INFORMATION SHEET

IV. Control factors of AC and DC motors

   A. AC control system drives an AC motor

   B. DC motors have limited speed changes to prevent damage to brushes and commutator

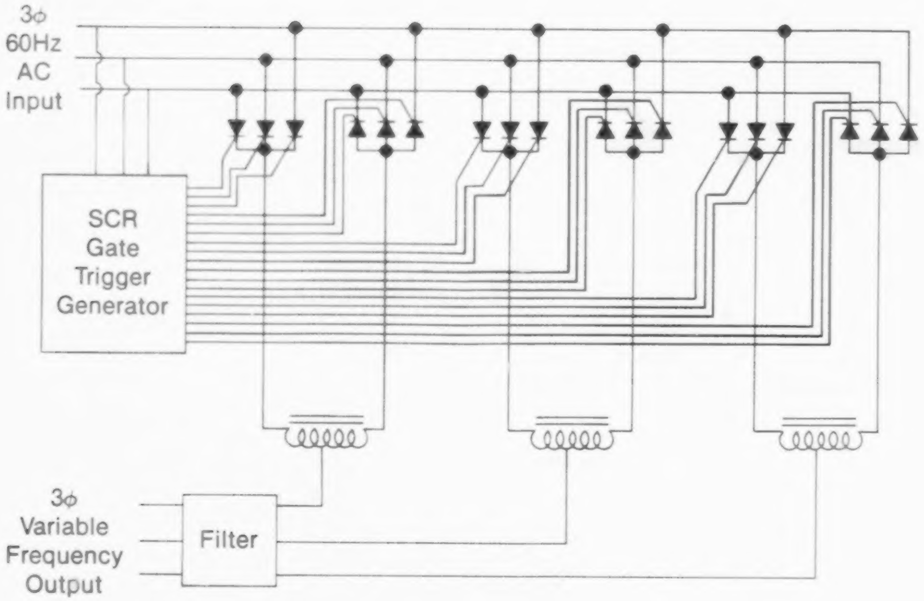
   C. AC motors are less expensive to operate and maintain

   D. AC motors are smaller than DC motors of equal HP

V. Types of converters and inverters (Figures 9-15)

   A. Cycloconverter

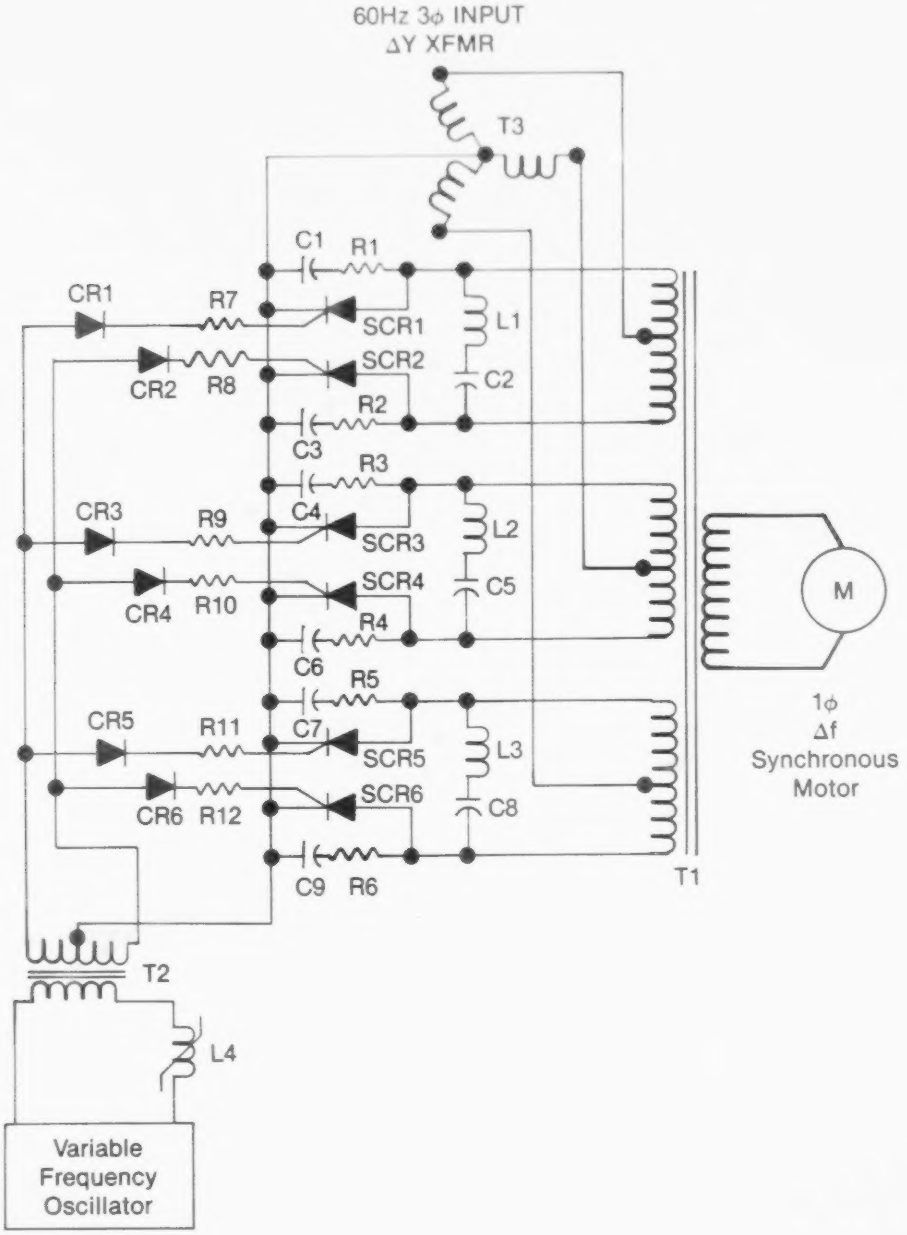
FIGURE 9


3ϕ
60Hz
AC
Input
SCR
Gate
Trigger
Generator
3ϕ
Variable
Frequency
Output
Filter

INFORMATION SHEET

B. Three phase to single phase converter

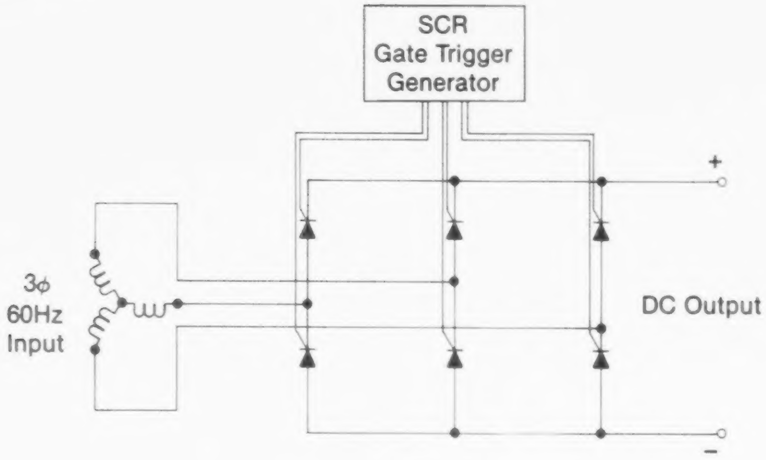
FIGURE 10


60Hz 3ϕ INPUT
ΔY XFMR
T3
C1
R1
CR1
R7
SCR1
L1
CR2
R8
SCR2
C2
C3
R2
R3
CR3
R9
C4
SCR3
L2
CR4
R10
SCR4
C5
R4
C6
M
R5
CR5
R11
C7
SCR5
L3
CR6
R12
SCR6
C8
C9
R6
T1
1ϕ
Δf
Synchronous
Motor
T2
L4
Variable
Frequency
Oscillator

INFORMATION SHEET

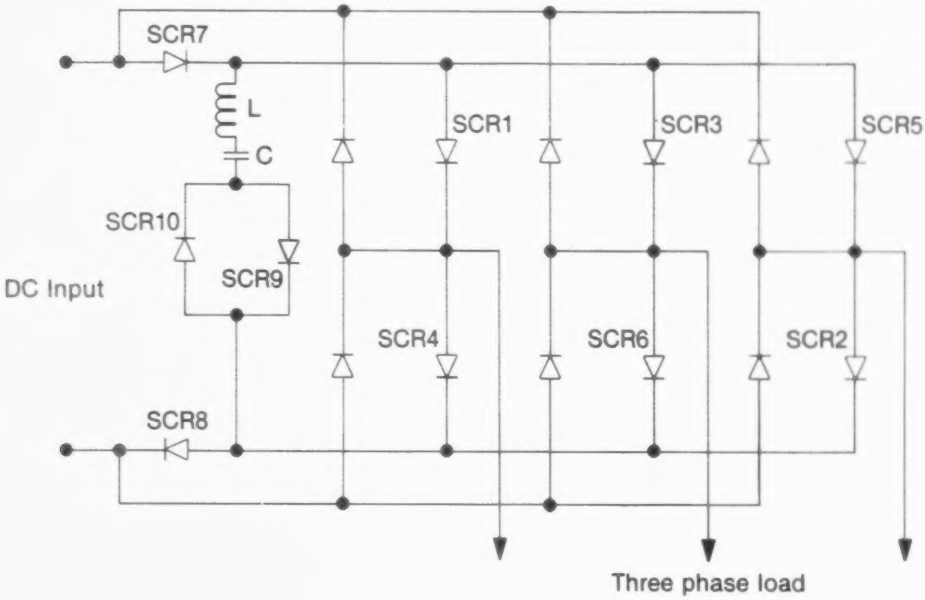
C. Full wave 3Φ inverter

FIGURE 11


SCR
Gate Trigger
Generator
+
3ϕ
60Hz
Input
DC Output
−

D. Parallel LC commutated bridge inverter

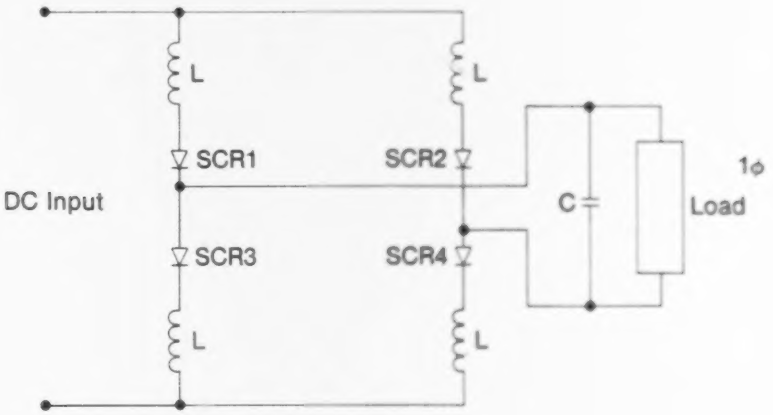
FIGURE 12


SCR7
L
C
SCR1
SCR3
SCR5
SCR10
SCR9
DC Input
SCR4
SCR6
SCR2
SCR8
Three phase load

INFORMATION SHEET

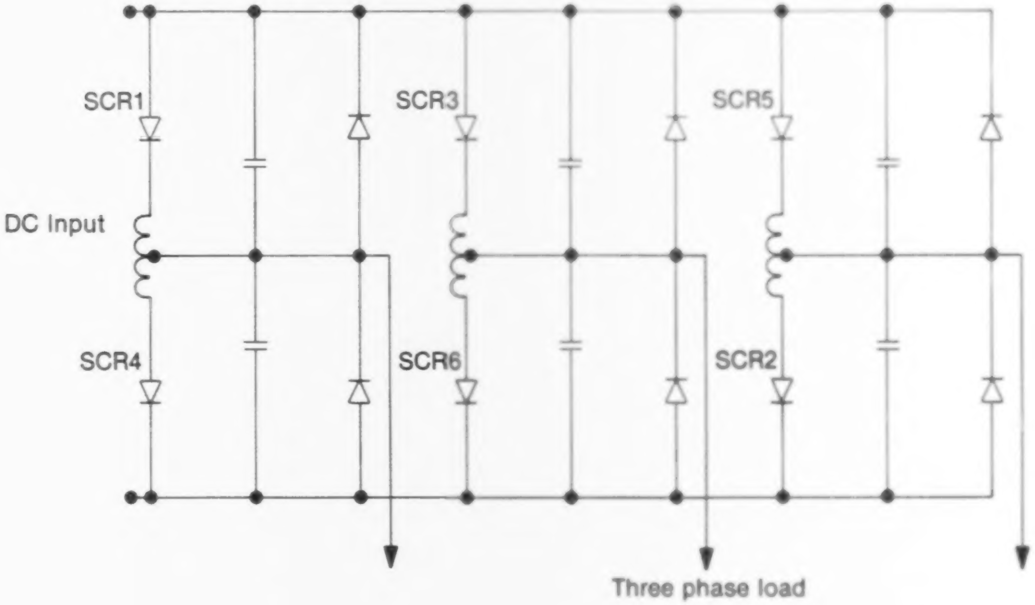
E. Series capacitor commutation bridge inverter

FIGURE 13


L
L
SCR1
SCR2
1ϕ
DC Input
C
Load
SCR3
SCR4
L
L

F. Coupled pulse commutated inverter

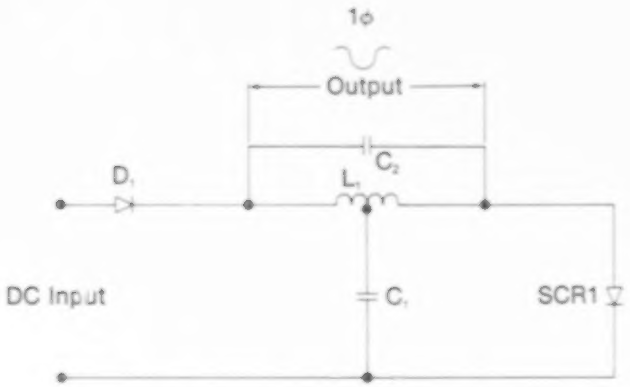
FIGURE 14


SCR1
SCR3
SCR5
DC Input
SCR4
SCR6
SCR2
Three phase load

INFORMATION SHEET

G. Economical series capacitor commutated inverter

FIGURE 15



VI. Types of AC motor controllers and their characteristics

A. Variable voltage input

1. Control of power may be from shaft-driven PMG or may be a frequency feedback loop

   (NOTE: Most controllers vary power to control torque while the motor speed varies according to frequency.)

2. Requires LC filtering on the DC inverter output

B. Current source inverter

1. Control of current is accomplished by current monitoring of AC input
2. Has best torque control
3. Requires quality inductive filtering of the DC link

C. Pulse width modulated

1. Often used for servo drives
2. Final state inverter controls both power and frequency (DC link voltage does not vary)

INFORMATION SHEET

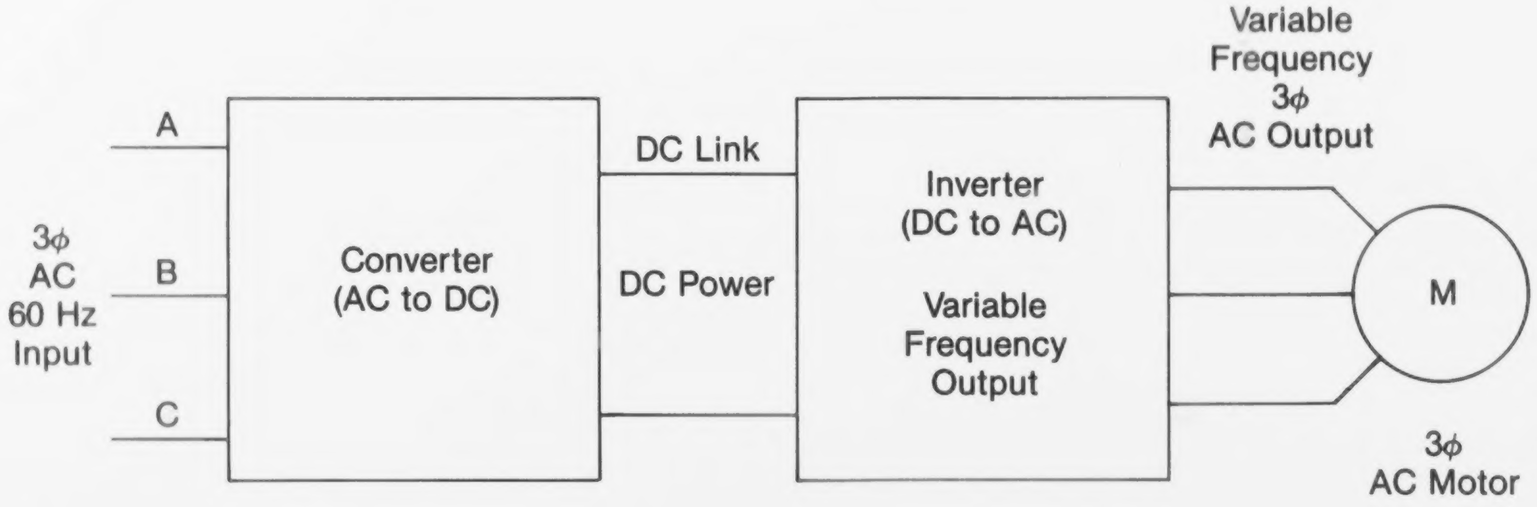
3. Regulating circuitry is most complex
4. Requires less DC filtering (full wave rectification is not chopped by SCRs)
5. Output is more sinusoidal

Power Circuit Terminology

		Input	
		A.C.	**D.C.**
Output	**A.C.**	Frequency Converter	Inverter
	D.C.	Rectifier	D.C. to D.C. Converter

(NOTE: In applications other than power, a circuit that converts AC of a high frequency to AC of a lower frequency may be called a down-converter. The opposite may be called an up converter.)

Simplified Block Diagram for an AC Controller



3ϕ
AC
60 Hz
Input

A
B
C

Converter
(AC to DC)

DC Link

DC Power

Inverter
(DC to AC)

Variable
Frequency
Output

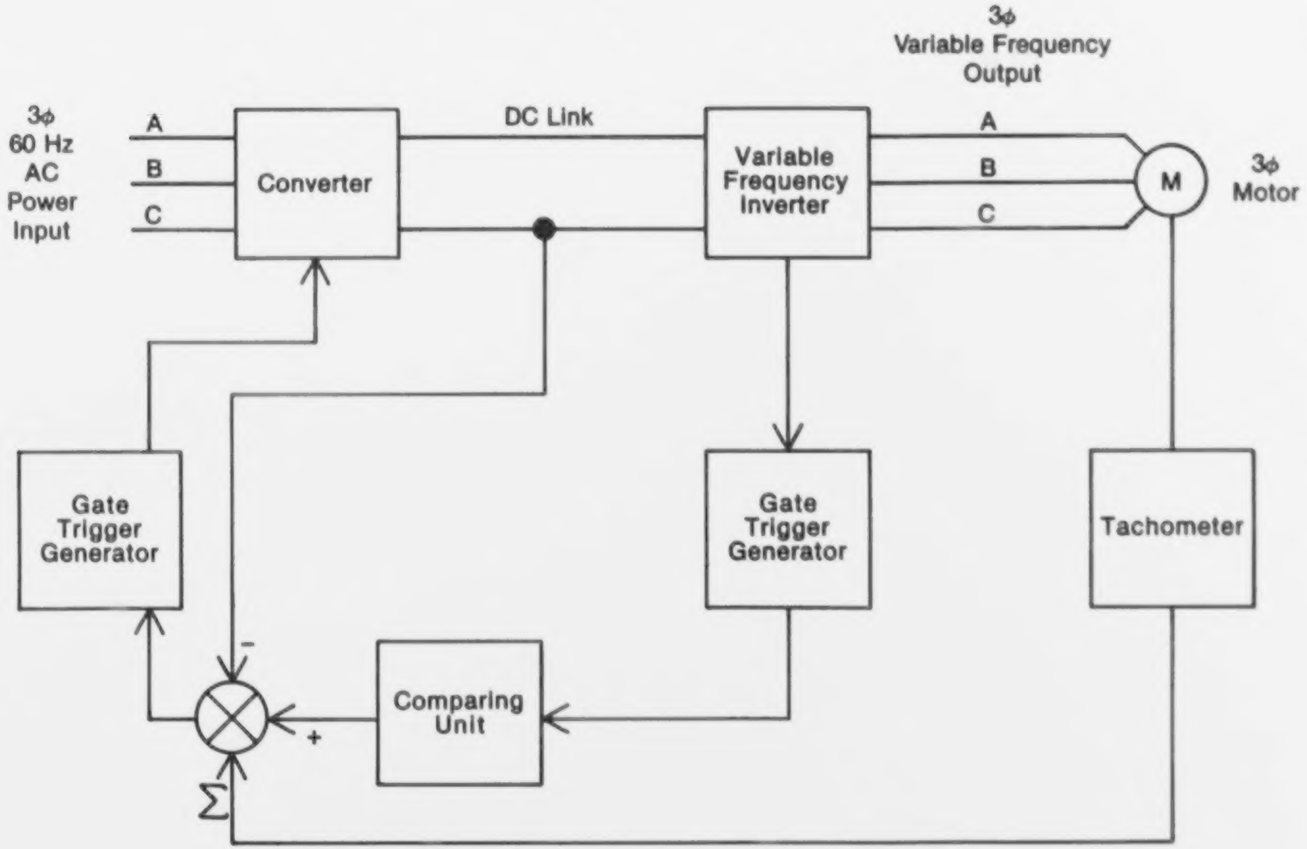
Variable
Frequency
3ϕ
AC Output

M

3ϕ
AC Motor

Closed Loop AC Controller Block Diagram

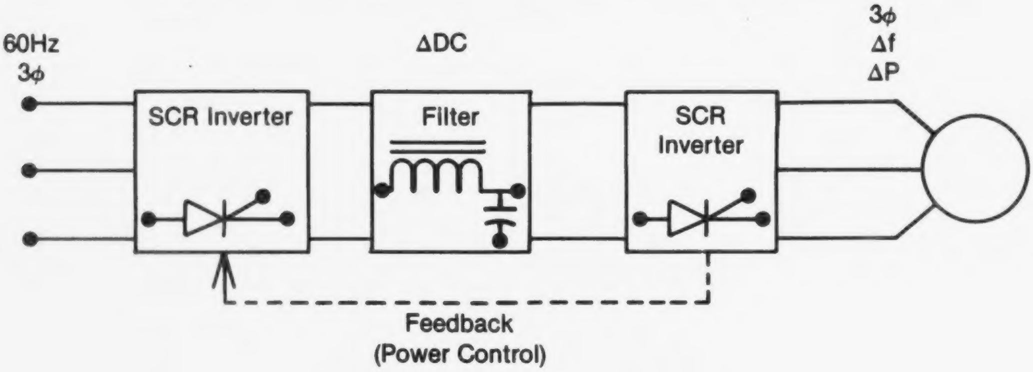
(Frequency)


3ϕ
Variable Frequency
Output
3ϕ
60 Hz
AC
Power
Input
A
B
C
Converter
DC Link
Variable
Frequency
Inverter
A
B
C
M
3ϕ
Motor
Gate
Trigger
Generator
Gate
Trigger
Generator
Tachometer
−
+
Comparing
Unit
Σ

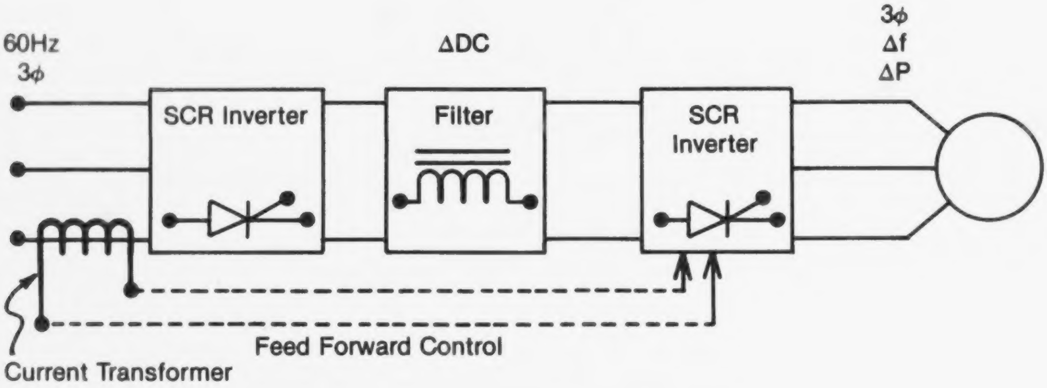
TM #3

PCT - 51-A

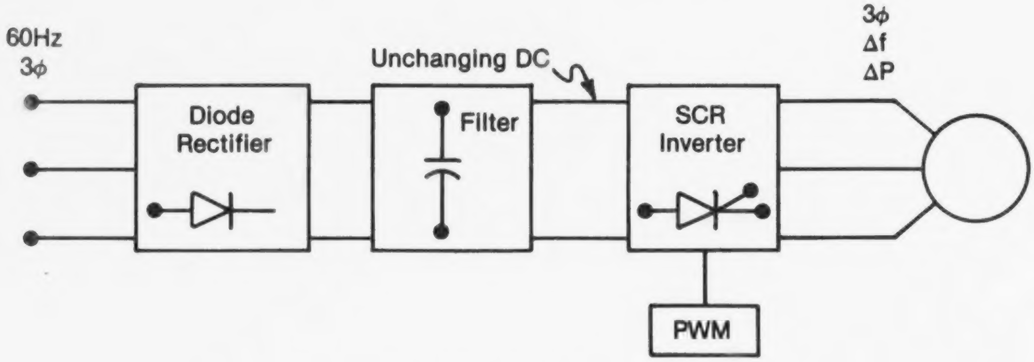
Types of AC Motor Controllers


60Hz
3ϕ
ΔDC
3ϕ
Δf
ΔP
SCR Inverter
Filter
SCR
Inverter
Feedback
(Power Control)

Variable Voltage Input


60Hz
3ϕ
ΔDC
3ϕ
Δf
ΔP
SCR Inverter
Filter
SCR
Inverter
Current Transformer
Feed Forward Control

Current Source Inverter


60Hz
3ϕ
Unchanging DC
3ϕ
Δf
ΔP
Diode
Rectifier
Filter
SCR
Inverter
PWM

Pulse Width Modulated

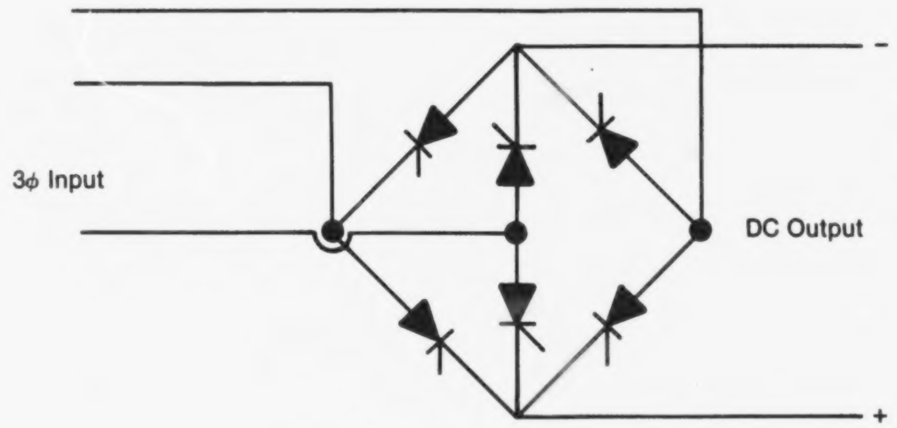
AC CONTROLLERS
UNIT II

ASSIGNMENT SHEET #1 — ANALYZE SCR INVERTER SCHEMATIC DIAGRAMS

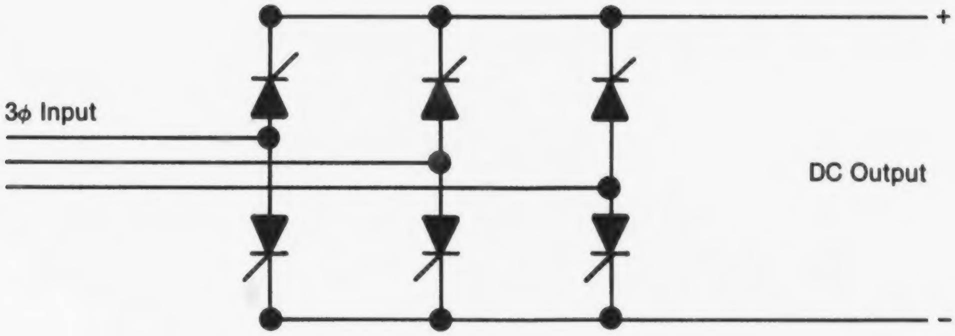
NAME ______________________________ SCORE ______________

An electronic technician must be able to read schematic diagrams to understand system operation and to perform troubleshooting. Study the circuits shown below and analyze the SCR inverters to output indicated in the drawing. Make any required changes to the drawings.

A.

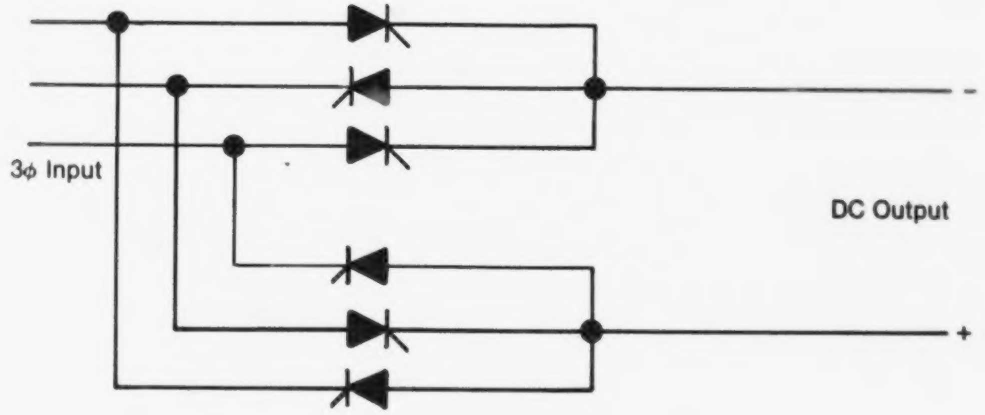


B.

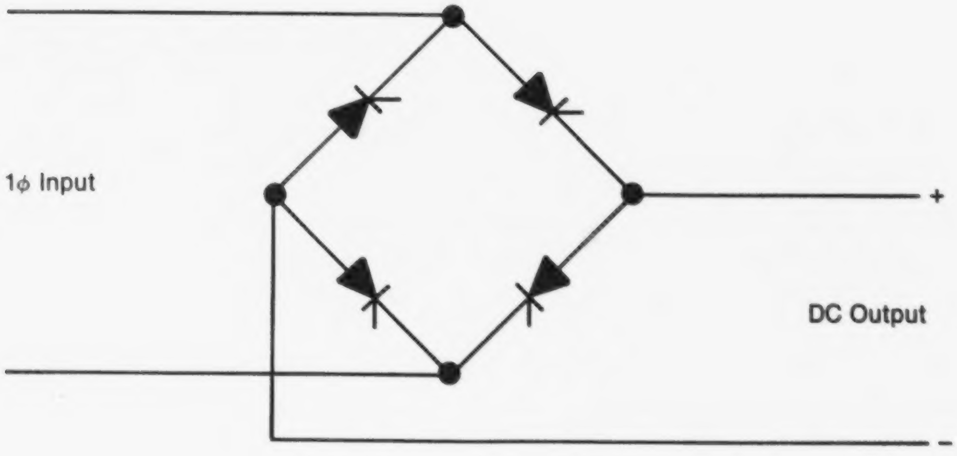


ASSIGNMENT SHEET #1

C.


3ϕ Input
DC Output
–
+

D.


1ϕ Input
DC Output
+
–

ASSIGNMENT SHEET #1

E. With the exception of any misoriented SCRs, are the circuits in A, B, and C identical?

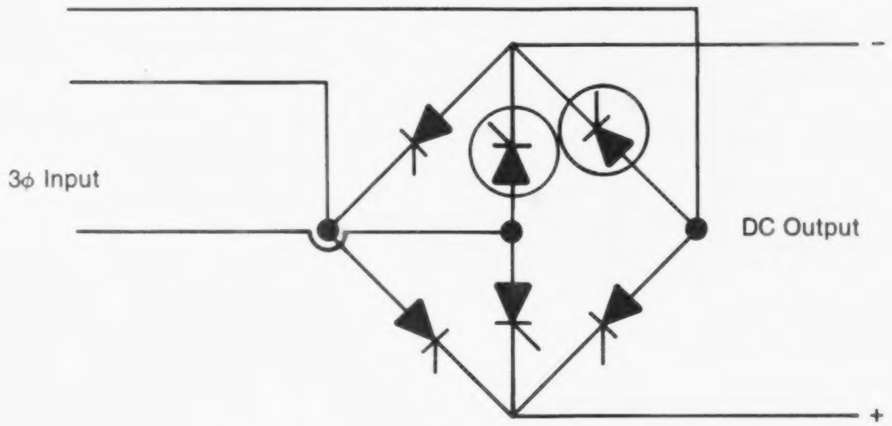
____

AC CONTROLLERS
UNIT II

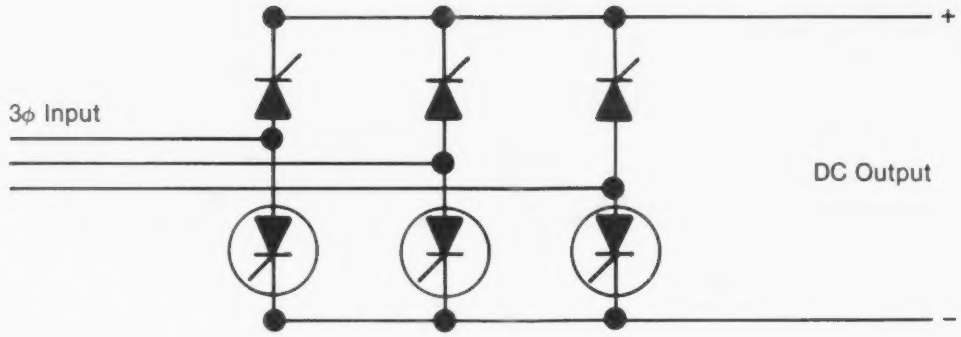
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.

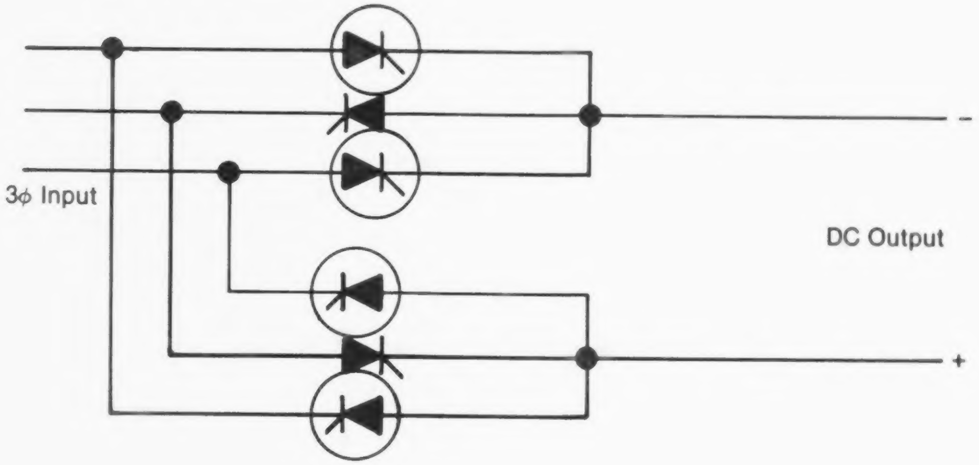

3ϕ Input
DC Output
−
+

B.

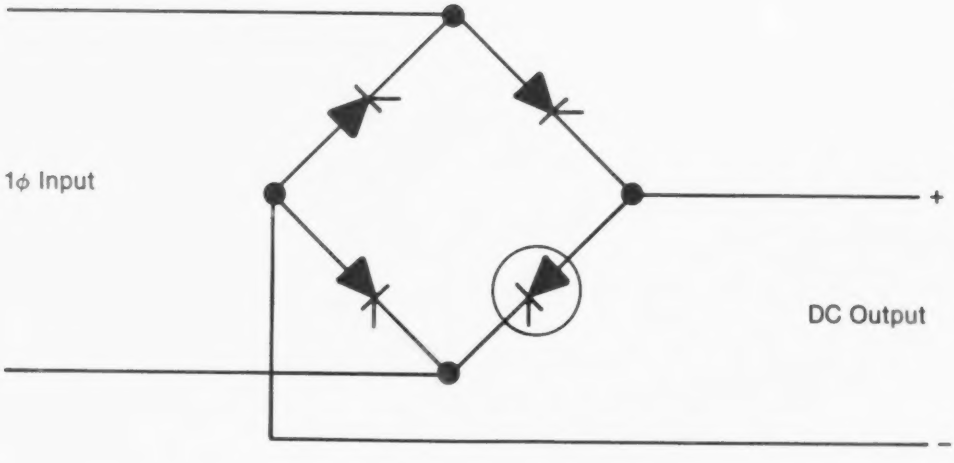

3ϕ Input
DC Output
+
−

ANSWERS TO ASSIGNMENT SHEETS

C.


3ϕ Input
DC Output
−
+

D.


1ϕ Input
DC Output
+
−

E. Yes

AC CONTROLLERS
UNIT II

JOB SHEET #1 — CONSTRUCT AND ANALYZE AN SCR INVERTER

I. Materials and equipment

A. SCR, type C40A, 2 each

B. Capacitor, 1 MF, 50V

C. Inductor, 1/2 mH, 1 each

D. Diode, 4007, 1 each

E. Capacitor, .22 MF, 25V, 2 each

F. Capacitor, .1 MF, 25V, 2 each

G. Transformer, 1:3.59, 24V, center tap

H. Transitor, NPN, 2N4238, 2 each

I. Resistor, 1W, 220 Ohms, 2 each

J. Resistor, 1/4 W, 2.2 Kohms, 2 each

K. Resistor, 1/4 W, 3.3 Kohms

L. Resistor, 1 W, 390 0hms, 2 each

M. Diode, 2 each

N. Lamp socket, 120 VAC, 2 each

O. Lamp, 120VAC, 15 W, 2 each

P. Potentiometer, 5.0 Kohms

Q. Power supply, must produce 28 volts at 2 amperes

R. Oscilloscope, dual trace, with leads

S. Breadboard for components or other means of assembly

T. Multimeter with probes

JOB SHEET #1

II. Procedure

A. Construct the circuit shown on the following page (Figure 16)

B. Connect the power supply

C. Connect the 15 watt lamps and sockets in series for an output load across the transformer

D. Ask your instructor to check you work

E. Turn on the DC power supply; the lamps should glow indicating that the circuit works

F. Adjust the potentiometer if necessary to make the circuit oscillate

G. Measure the parameters listed below and record the values

1. Frequency of output ______________________ Hz

2. Voltage of output ______________________ VAC-RMS

H. Sketch the waveform at one SCR gate in the space below

I. Sketch the waveform at one SCR anode in the space below

J. Sketch the waveform at the transformer centertap in the space below

K. Use the oscilloscope dual trace to look at the wave form at the base of one transistor and the anode of the associated SCR

L. Show the display to your instructor

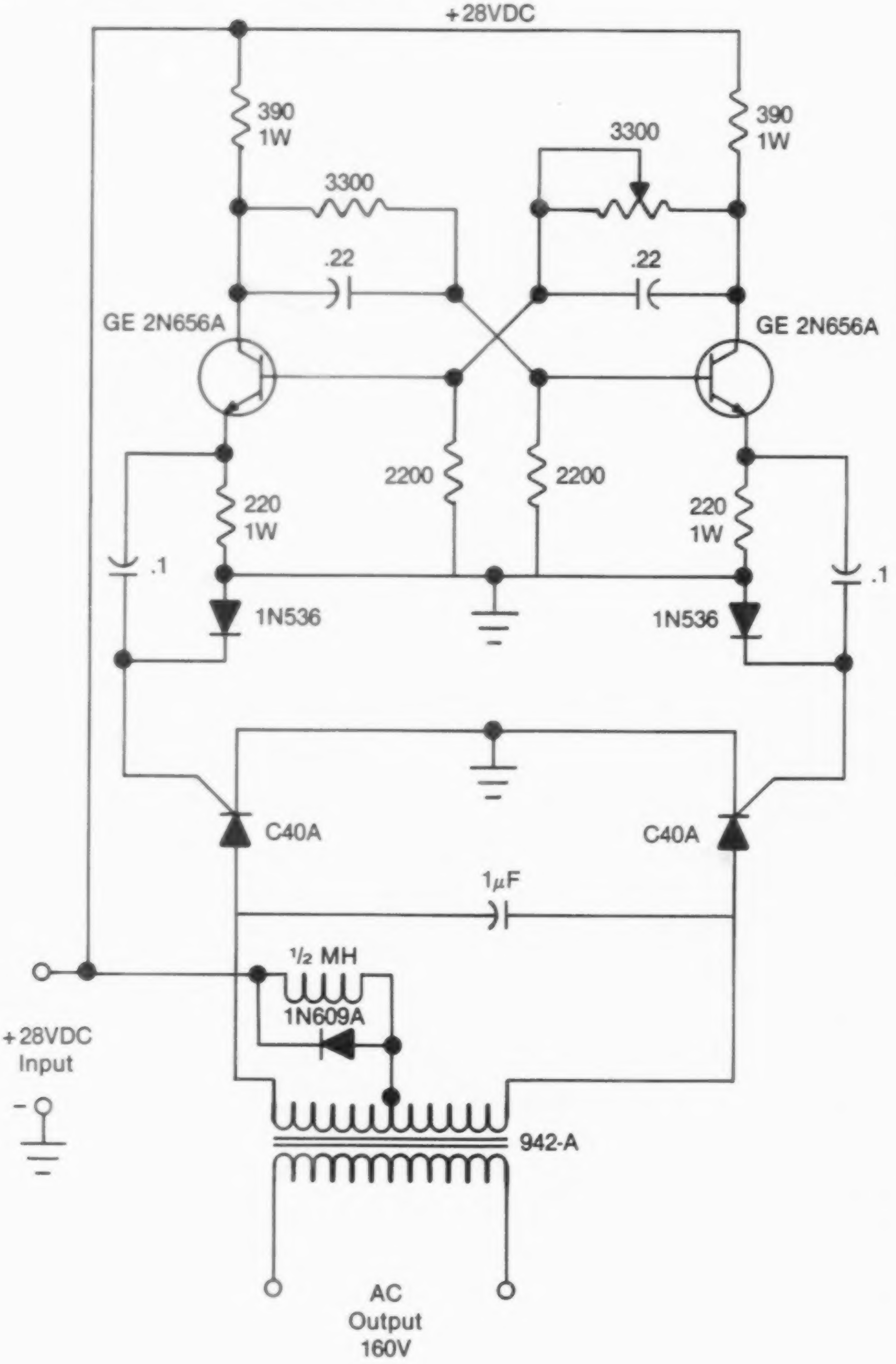
M. Use the oscilloscope to measure output of the circuit

N. Show the display to your instructor and discuss the results

O. Put away tools and equipment

JOB SHEET #1

FIGURE 16


+28VDC
390
1W
390
1W
3300
3300
.22
.22
GE 2N656A
GE 2N656A
2200
2200
220
1W
220
1W
.1
.1
1N536
1N536
C40A
C40A
1μF
½ MH
1N609A
+28VDC
Input
-
942-A
AC
Output
160V

AC CONTROLLERS
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with AC controllers to the correct definitions. Write the correct number in the blanks.

_____a. Motor which operates at precise speeds to position mechanical systems

_____b. Method of varying the pulse width to load for variable output control

_____c. Device which transforms AC to pulsating DC

_____d. Method of output control by sampling output results for comparison with desired results

_____e. Resembling a sine wave or sine funtion

_____f. Force which produces rotation about an axis

_____g. Any of the mechanical, electrical, hydraulic or electronic systems which allow motor speed control

_____h. Device which transforms DC to AC

_____i. Device which varies the AC waveform to control an AC load such as a motor

_____j. Device which transforms AC of one frequency to AC of another frequency

1. AC controller
2. Inverter
3. Rectifier
4. Frequency converter
5. Variable speed driver
6. Torque
7. Sinusoidal
8. Servo motor
9. Pulse width modulation
10. Closed loop control

TEST

2. Match symbols and abbreviations associated with AC controllers to their correct interpretations. Write the correct numbers in the blanks.

______a. Phase

______b. Hertz

______c. Variable frequency oscillator

______d. Crystal rectifier

______e. Permanent magnet generator (tachometer)

______f. Voltage controlled oscillator

______g. Digital to analog converter

______h. Summing circuit

______i. Computer numerical control

______j. Silicon controlled rectifier

______k. Silicon unilateral switch

______l. Three phases of AC 3Φ power

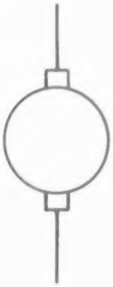
______m. Pulse width modulation

1. Hz
2. Φ
3. PWM
4. CNC
5. SCR
6. SUS
7. CRX
8. A, B, C
9. VCO
10. D/A
11. Σ
12. VFO
13. PMG

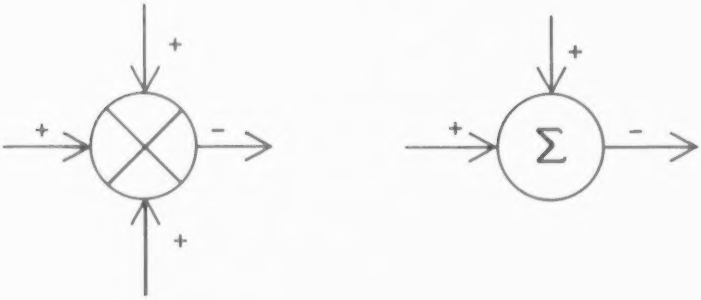
TEST

3. Identify schematic symbols associated with AC controllers. Write the correct names in the blanks.

Summing circuit
Saturable core reactor
AC motor
DC motor
Wye transformer arrangement
Delta transformer arrangement
Auto transformer

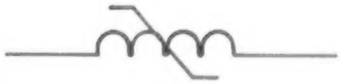


a. ______________________________

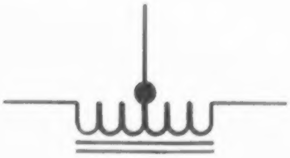


b. ______________________________

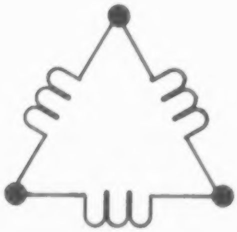
TEST



c. ______________________________

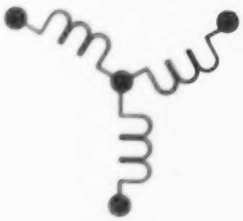


d. ______________________________

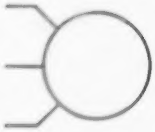


e. ______________________________

TEST



f. ____



g. ____

4. Select from the following list correct statements comparing AC and DC motor control. Write an "X" before each correct statement.

_____a. AC control system drives an AC motor

_____b. DC motors are smaller than AC motors of equal HP

_____c. AC motors are smaller than DC motors of equal HP

_____d. DC motors are less expensive to operate and maintain

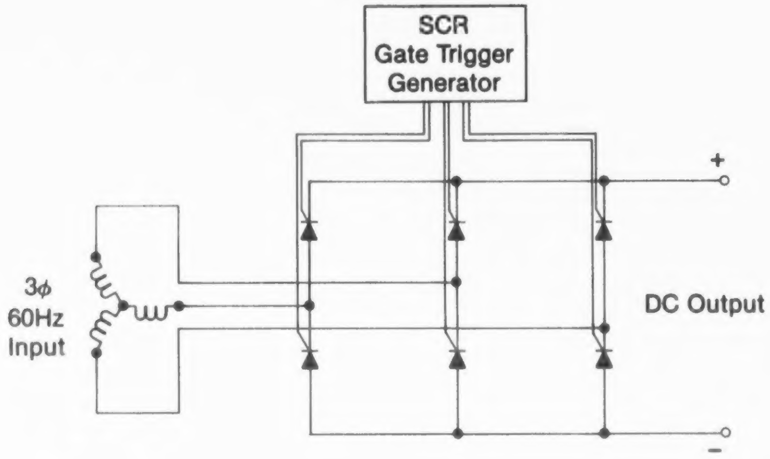
_____e. AC motors are less expensive to operate and maintain

_____f. DC motors have limited speed changes to prevent damage to the brushes and commutator

TEST

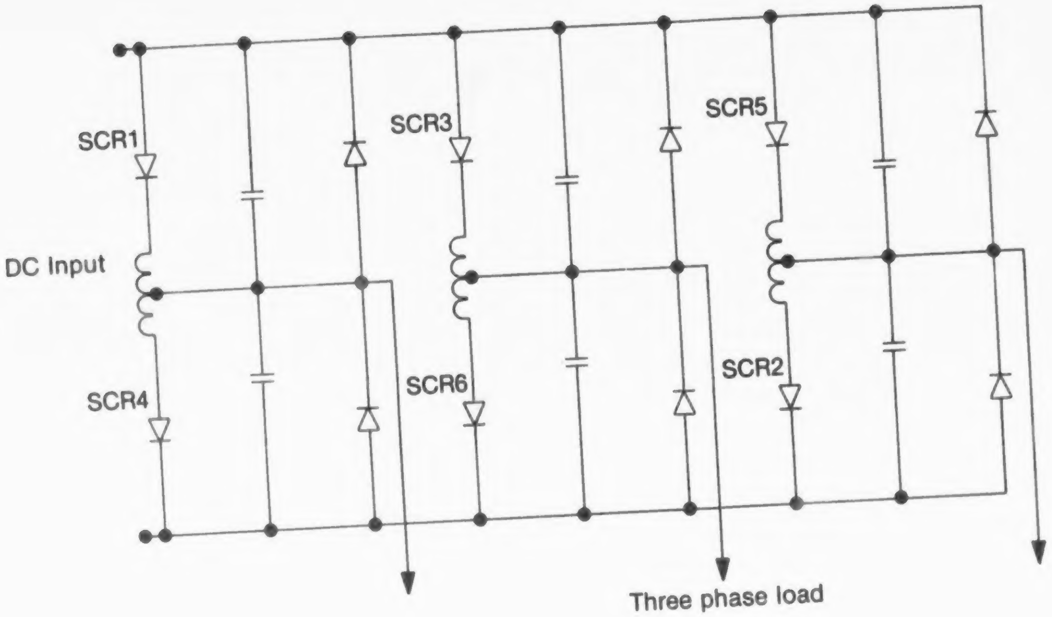
5. Identify inverter and converter schematic diagrams. Write the correct names in the blanks.

Cycloconverter
Three phase to single phase converter
Full wave 3Φ inverter
Parallel LC commutated bridge inverter
Series capacitor commutation bridge inverter
Coupled pulse commutated inverter
Economical series capacitor commutated inverter

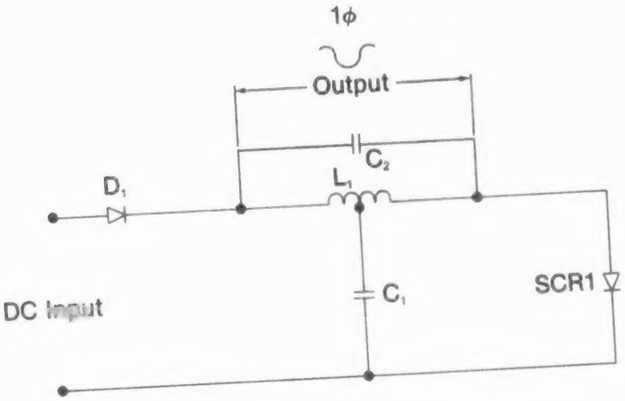

SCR
Gate Trigger
Generator
+
3ϕ
60Hz
Input
DC Output
–

a. ______________________________________

TEST

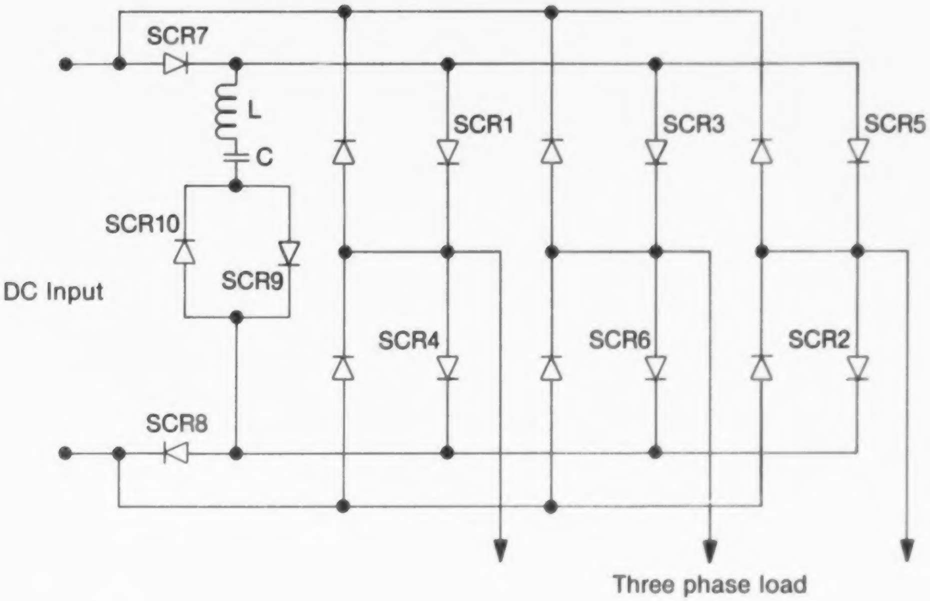

SCR1
SCR3
SCR5
DC Input
SCR4
SCR6
SCR2
Three phase load

b. ______________________________

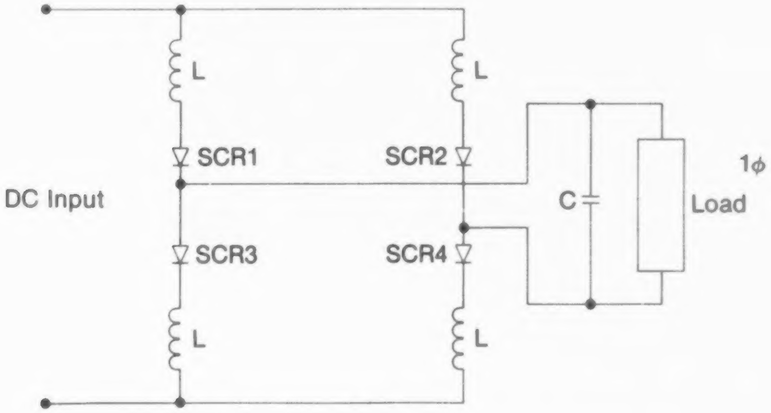

1ϕ
Output
C_2
D_1
L_1
C_1
SCR1
DC Input

c. ______________________________

TEST

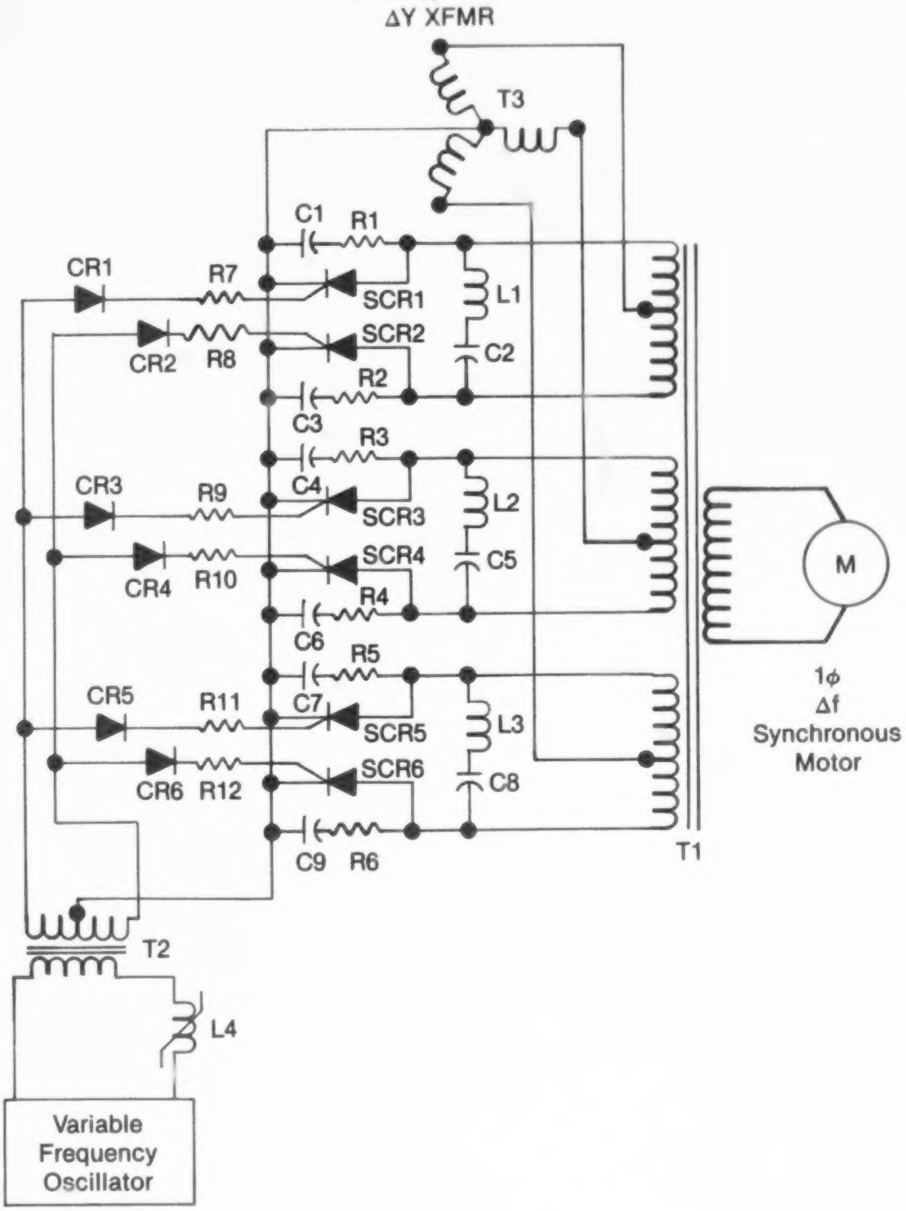

SCR7
L
C
SCR1
SCR3
SCR5
SCR10
SCR9
DC Input
SCR4
SCR6
SCR2
SCR8
Three phase load

d. ______________________________


L
L
SCR1
SCR2
1ϕ
DC Input
C
Load
SCR3
SCR4
L
L

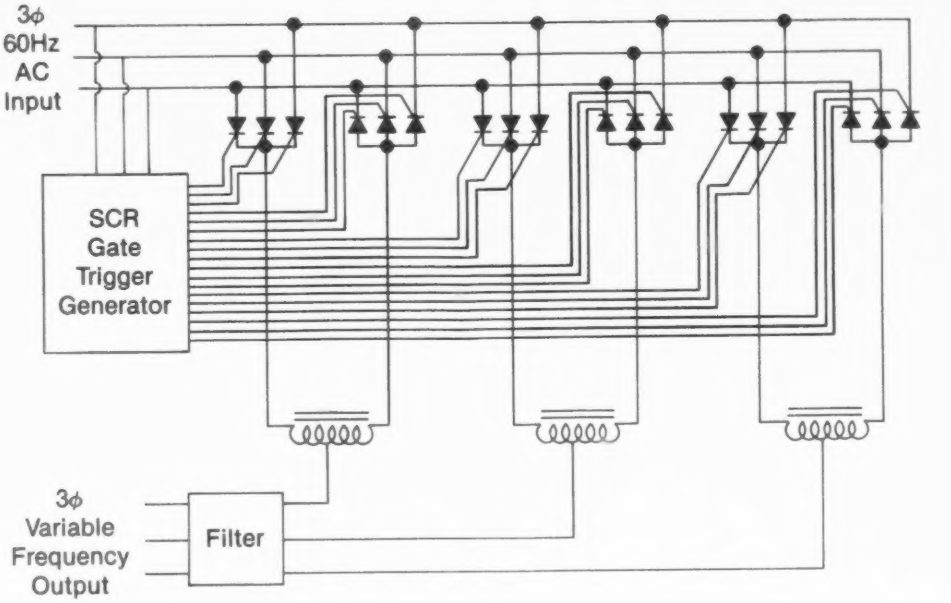
e. ______________________________

TEST


60Hz 3ϕ INPUT
ΔY XFMR
T3
C1
R1
CR1
R7
SCR1
L1
CR2
R8
SCR2
C2
R2
C3
R3
CR3
R9
C4
SCR3
L2
CR4
R10
SCR4
C5
R4
C6
R5
CR5
R11
C7
SCR5
L3
CR6
R12
SCR6
C8
C9
R6
T1
M
1ϕ
Δf
Synchronous
Motor
T2
L4
Variable
Frequency
Oscillator

f. ______________________________

TEST


3ϕ
60Hz
AC
Input
SCR
Gate
Trigger
Generator
3ϕ
Variable
Frequency
Output
Filter

g. ______________________________

TEST

6. Distinguish between types of AC motor controllers and their correct characteristics. Write the correct numbers in the blanks. A number may be used more than once.

_____a. Output is more sinusoidal

_____b. Has best torque control

_____c. Requires less DC filtering (full wave rectification is not chopped by SCRs)

_____d. Control of power may be from shaft-driven PMG or may be a frequency feedback loop

_____e. Control of current is accomplished by current monitoring of AC input

_____f. Requires LC filtering on the DC inverter output

_____g. Often used for servo drives

_____h. Final stage inverter controls both power and frequency (DC link voltage does not vary)

_____i. Requires quality inductive filtering of the DC link

_____j. Regulating circuitry is most complex

1. Pulse width modulated
2. Variable voltage input
3. Current source inverter

(NOTE: Test questions 7 and 8 are the assingment sheet and job sheet. They are an important part of this test. If they have not been completed, check with your instructor.)

7. Analyze SCR inverter schematic diagrams.

8. Demonstrate the ability to construct and analyze an SCR inverter.

AC CONTROLLERS
UNIT II

ANSWERS TO TEST

1. a. 8
   b. 9
   c. 3
   d. 10
   e. 7
   f. 6
   g. 5
   h. 2
   i. 1
   j. 4

2. a. 2
   b. 1
   c. 12
   d. 7
   e. 13
   f. 9
   g. 10
   h. 11
   i. 4
   j. 5
   k. 6
   l. 8
   m. 3

3. a. DC motor
   b. Summing circuit
   c. Saturable core reactor
   d. Auto transformer
   e. Delta transformer arrangement
   f. Wye transformer arrangement
   g. AC motor

4. a, c, e, f

5. a. Full wave 3Φ inverter
   b. Coupled pulse commutated inverter
   c. Economical series capacitor commutated inverter
   d. Parallel LC comutated bridge inverter
   e. Series capacitor commutation bridge inverter
   f. Three phase to single phase converter
   g. Cycloconverter

6. a. 1
   b. 3
   c. 1
   d. 2
   e. 3
   f. 2
   g. 1
   h. 1
   i. 3
   j. 1

7. Evaluated to the satisfaction of the instructor.

8. Performance skills evaluated to the satisfaction of the instructor.

POWER FACTOR REGULATION
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to use test equipment to monitor and evaluate the quality of AC power. The student will show this knowledge be completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with power factor regulation with their correct definitions.
2. State meaning of abbreviations associated with power factor regulation.
3. Identify one-line diagram symbols associated with power factor regulation.
4. Describe types of electrical interference.
5. Complete statements about considerations in power regulation.
6. Match test equipment to their correct uses.
7. Match categories of auxiliary power systems with their characteristics.
8. Demonstrate ability to
   a. Monitor the quality of AC power.
   b. Connect power-factor correcting capacitors to a motor circuit.
   c. Use an oscilloscope to detect transients in AC power.

POWER FACTOR REGULATION
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Provide students with information, assignment, and job sheets.

  D. Discuss unit and specific objectives.

  E. Discuss information and assignment sheets.

  F. Demonstrate and discuss procedures outlined in job sheets.

  G. Demonstrate the use of test equipment discussed in this unit such as megohmmeter, power factor meter, watt meter, phase sequence indicator, and strip-chart recorder.

  H. Visit a plant in your area and show students power factor regulation equipment.

  I. Invite someone from a local electrical utility company to discuss power factor and other aspects of power quality.

  J. Review the National Electrical Code sections pertaining to power-factor capacitors and emergency power systems.

  K. Emphasize the safety rules and precautions necessary when working with hazardous voltages and large current capacity devices as associated with this unit.

  L. Give test.

  M. Critique test.

  N. Reteach if necessary.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

  D. Assignment sheets

    1. Assignment Sheet #1 — Determine Answers to Specific Questions by Consulting the National Electrical Code

    2. Assignment Sheet #2 — Analyze a One-Line Diagram

SUGGESTED ACTIVITIES

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1 — Monitor the Quality of AC Power

2. Job Sheet #2 — Connect Power-Factor Correcting Capacitors to a Motor Circuit

3. Job Sheet #3 — Use an Oscilloscope to Detect Transients in AC Power

G. Test

H. Answers to test

III. Unit references

A. Stromme, George. "Multiple Levels and Classifications of Emergency Electrical Power Systems," *IEEE Transactions on Industry Applications*, Vol. IA-17, No. 5, Sept./Oct. 1981, pp. 469-472.

B. *Power Factor Improvement*. Stillwater, Oklahoma: Oklahoma State University, School of Technology, Electrical Power Technology Department, 1977.

C. *Power Factor Correction, Manual PF-1000*. North Adams, Massachussetts: Industrial Capacitor Department, Sprague Electric Co., 1962.

D. *National Electrical Code*. Boston, Massachussetts: National Fire Protection Association, 470 Atlantic Ave., 1981.

E. Stewart, Jay A. "1981 National Electrical Code Revisions: Emergency and Legally Required Standby and Optional Standby Systems," *IEEE Transactions on Industry Applications*, Jan./Feb. 1982, Vol. IA-18, No. 1, pp. 16-18.

POWER FACTOR REGULATION
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Transient (spike) — High voltage disturbance lasting less than 500 microseconds

B. Voltage surge — High voltage disturbance lasting longer than 500 microseconds

C. Current surge — Temporary high current condition on a line

D. Suppressor — Circuit that impedes transients

EXAMPLES: Metal oxide varistors, silicon diode suppressor, gas discharge tubes

E. Overcurrent protection — Device which protects power circuits from excessive current

EXAMPLES: Fuses, circuit breakers, heater elements in starters

(NOTE: Ground fault detection and interrupting are required in some cases in addition to overcurrent protection [which is always required] since a ground fault may not always be sufficient to trip an overcurrent device.)

F. Ground fault — Electrical short-circuit to ground

G. Thyristor — Any of the rapid firing devices such as SCRs, TRIACs, etc.

H. Reactance — Opposition to current or voltage changes due to inductance or capacitance

I. True power — All power dissipated by resistance in a circuit

J. Reactive power — AC power stored as an electrical field in a capacitor or a magnetic field around an inductor

K. Apparent power — Sum of true power and reactive power

(NOTE: The formula for apparent power is $P_A = E_A \times I_A$.)

L. Power factor — Percentage of true AC power compared to apparent AC power

EXAMPLE: A 95% power factor is interpreted as true power being 95% of apparent power. In other words, there is a 5% loss of power due to unbalanced reactance.

INFORMATION SHEET

(NOTE: The extremes of the power factor range from 100 percent or 1 in a purely resistive circuit to 0 in a purely reactive circuit.)

M. Phase-reversal — Result of 3ϕ power having any two phases switched

(NOTE: Switching any two leads to a 3ϕ motor will cause it to run in reverse.)

N. Demand control — Controlling the power being used at particular times of the day

O. Peak demand — Time of year or time of day when power usage is maximum

EXAMPLE: Hot summer days at mid-afternoon when air conditioners are being used a great deal

II. Abbreviations and acronyms

A. Var — Volt-ampere reactive power

B. PF — Power factor

C. Va — Volt-ampere

D. Kvar — Kilo-volt-ampere reactive

(NOTE: Volt-amperes and volt-amperes reactive are often given in thousands, or kilo-volt-amperes [kva] and kilo-volt-amperes reactive [kvar].)

E. EMI — Electromagnetic interference

F. RFI — Radio frequency interference

G. CI — Conducted interference

H. GFP — Ground fault protection

I. CB — Circuit breaker

J. NEC — National Electrical Code

K. Sec. — Section of NEC

L. OCR — Oil circuit recloser

M. OCB — Oil circuit breaker

N. ACR — Automatic circuit recloser

O. SCR — Silicon controlled rectifier

INFORMATION SHEET

P. GFI — Ground fault interrupter

Q. UPS — Uninterruptable power supply

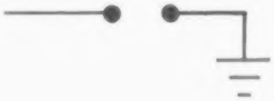
R. EEPS — Emergency electrical power system

III. One-line diagram symbols (Figures 1-14)

A. Voltage surge protection

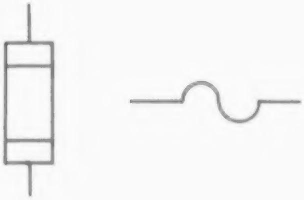
(NOTE: This figure illustrates an arc gap suppressor or a spark gap suppressor.)

FIGURE 1



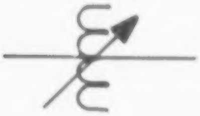
B. Overcurrent protection (fuse)

FIGURE 2



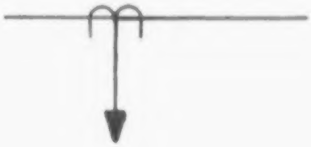
C. Voltage regulating transformer

FIGURE 3



D. Metering current transformer

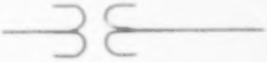
FIGURE 4



INFORMATION SHEET

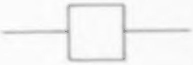
E. Potential transformer

FIGURE 5



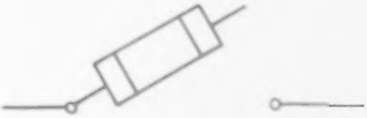
F. Breakers, OCR, OCB, ACR, etc.

FIGURE 6



G. Fused disconnect

FIGURE 7



H. Breaker with thermal overload

FIGURE 8

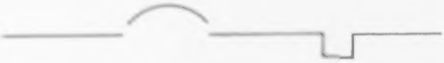
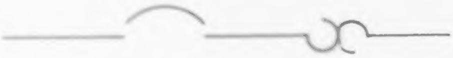


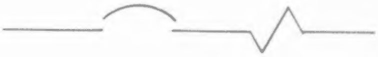
FIGURE 9



INFORMATION SHEET

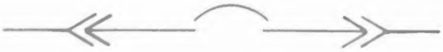
I. Breaker with magnetic overload

FIGURE 10



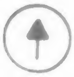
J. Drawout type breaker

FIGURE 11



K. Current source

FIGURE 12



L. Capacitive diode (varactor)

FIGURE 13

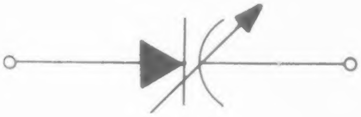
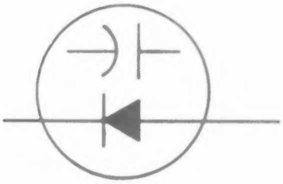


FIGURE 14



INFORMATION SHEET

IV. Types of electrical interference

A. Electromagnetic interference (EMI) — Electrical noise induced on an AC power line when a magnetic field momentarily envelops the AC power line

EXAMPLES: Lightning, welders

B. Radio frequency interference (RFI) — Undesirable interference within the radio frequency spectrum (30 K - 30,000 MHz)

(NOTE: RFI is often caused in 60 Hz power line and can usually be filtered out.)

C. Conducted interference (CI) — Noise applied directly to power lines by loads

(NOTE: CI is conducted from the load through other parts of the electrical circuit, such as other parts of a building or into other buildings on the same circuit. CI diminishes in strength as it travels away from its source.)

EXAMPLES: Appliances, power tools, electric motors

D. Common-mode interference — Noise that appears between the terminals of a measuring circuit and ground

V. Considerations in power regulation

A. Control of power factor

1. To save costs of electrical power

(NOTE: Most power supply companies penalize users with low power factors by considering power factor in the rates charged for power.)

2. To allow equipment to operate cooler

(NOTE: An electrical motor operating with a low power factor will demand more current which will create more heat in the windings.)

3. To conserve energy

(NOTE: Conservation of limited natural resources, such as the coal required to produce electricity, will contribute to national welfare.)

4. Requires balancing inductive and capacitive reactances

(NOTE: Most industries add large capacitors to their AC power distribution lines to offset the effects of inductance.)

INFORMATION SHEET

5. Transformers, motors, arc welders, and electromagnets lower the power factor

   (NOTE: Most plants are too inductive because of the use of motors and transformers.)

B. Control of voltage

1. May be required for critical or sensitive equipment to prevent damage or malfunction due to low voltage or high voltage conditions

   EXAMPLES: Computers, electronic controls, precisely controlled electrochemical processes

2. May be required for ordinary equipment if supply voltage varies significantly

   (NOTE: Remote regions may experience significant voltage variations with seasonal demands. Some heavily populated areas experience "brownouts" during peak loads on hot summer days. Small municipal power companies switch generators off and on or connect to other supplies, causing voltage variations.)

C. Protection from transients due to interference

1. To protect voltage-sensitive electronic circuitry

   (NOTE: Electronic circuits are sensitive to overvoltage or interference.)

2. To isolate noise-generating machinery (conducted interference)

   (NOTE: Some electronic circuits, such as equipment using large thyristors, create transients which can travel throughout a plant. These transients result from the rapid switching that thyristors perform. It may be more effective to isolate one noise-generating machine than to protect several other noise-sensitive machines. A simple isolation transformer is somewhat effective in reducing transient transmission.)

3. May be required to reduce radio interference

   (NOTE: Most RFI is radiated noise and is most easily prevented by maintaining metal covers and panels on machinery along with proper bypassing and grounding techniques as well as good electrical wiring practices. Motors, electrical switches, and other devices that interrupt current generate RFI.)

D. Standby or emergency power

1. May be necessary to protect life or prevent injury

   EXAMPLES: Hospital equipment; exit lights; dangerous process controls, such as explosive chemical processing

INFORMATION SHEET

2. May be necessary for medium to large computers to protect against loss of data

3. May be necessary to prevent damage to equipment, loss of production, or loss of product material

   EXAMPLE: Power fluctuations to a CNC milling machine might lead to inaccurate or damaged parts or to equipment damage.

4. May include generating equipment or battery storage

   EXAMPLES: Diesel, natural gas, or other fueled generators may automatically start when power fails. Battery banks may continually charge while power is on and automatically supply power through an inverter when power fails.

E. Ground fault detection

1. May be required by national or local codes

   (NOTE: Ground fault detection is required for industrial 3ϕ 480/277 wye circuits by the NEC Sec. 230-95.)

2. Can protect wiring from extensive damage due to arcing to ground

F. Phase monitoring

1. To protect 3ϕ electrical equipment from operating with a loss of phase

2. To protect 3ϕ electrical equipment from phase reversal

G. Energy demand control

1. May be required by electrical utility companies to reduce peak demand

   (NOTE: Certain electrical utility companies do not have the capacity to supply enough power during high usage times and require industries to control their usage by staging eequipment.)

2. Can reduce an industry's electrical costs substantially

   (NOTE: Many power supply companies charge more for power used during the peak demand times.)

VI. Test equipment

A. Infrared thermometer — Used to scan electrical equipment for overloads and short circuits which create excessive heat

B. Strip-chart recorder — Used to record voltage and current variations

C. Watt/Watt-hour meter — Used to measure power consumption

D. Power factor meter — Used to measure reactive power

INFORMATION SHEET

E. Phase sequence indicator — Used to indicate 3ϕ power phase relationship

F. Megohmeter (megger®) — Used to detect high voltage leakage or shorts and to check ground connections

> **CAUTION**
>
> Meggers® produce sufficient voltage to cause injury or death. Ohmmeters are not sufficient to find high-voltage faults. Meggers should be used on all electrical equipment of 230 volts or more to ensure insulation and condition of equipment is satisfactory after installation or rework. Meggers should not be used on, near, or around electronic equipment.

(NOTE: Megger® is a registered trademark of Biddle Instruments, Blue Bell, PA 19422.)

VII. Auxiliary power systems

A. Emergency systems (Article 700, NEC)

1. Legally required by local, state, and federal codes
2. Essential for human life and safety
3. Required where large crowds may gather indoors
4. Aid in exiting buildings
5. Must be used for lighting, ventilation, elevators, fire pumps, public communications, and dangerous industrial process control when threat to public is likely

B. Legally required standby systems (Article 701, NEC)

1. Legally required by local, state, and federal codes
2. Provide for fire fighting, rescue, health hazard prevention, etc.
3. Must be used for heating, refrigeration, ventilation, lighting, and industrial process control where potential danger to public exists

C. Optional standby systems (Article 702, NEC)

1. Provide power to protect business or property from loss
2. Provide power where loss would damage equipment, interrupt production, or cause discomfort or inconvenience
3. May be used for computers, refrigeration, communications, industrial processes, or any user determined need

POWER FACTOR REGULATION
UNIT III

ASSIGNMENT SHEET #1 — DETERMINE ANSWERS TO SPECIFIC QUESTIONS BY CONSULTING THE NATIONAL ELECTRICAL CODE

NAME ______________________________ SCORE ______________

Industrial electronic technicians must be certain that their work is reliable, efficient, safe, and legal. Much of a technician's work is regulated by numerous local, state, and federal agencies.

Consult the NEC manual and answer the following questions.

1. Can an emergency power source be connected to provide power for optional equipment also?

   Answer ____________ Article ____________ Section ____________

2. Is the location of an emergency generator a concern of the NEC?

   Answer ____________ Article ____________ Section ____________

3. Are there any exceptions to the installation of ground fault protection?

   Answer ____________ Article ____________ Section ____________

4. Is maintenance required by the NEC for emergency power supplies?

   Answer ____________ Article ____________ Section ____________

5. What is the maximum allowed time for an emergency power supply to provide the power after loss of the normal supply?

   Answer ____________ Article ____________ Section ____________

6. What article of the NEC concerns capacitors used for power factor correction?

   ____

POWER FACTOR REGULATION
UNIT III

ASSIGNMENT SHEET #2 — ANALYZE A ONE-LINE DIAGRAM

NAME ______________________________ SCORE ____________

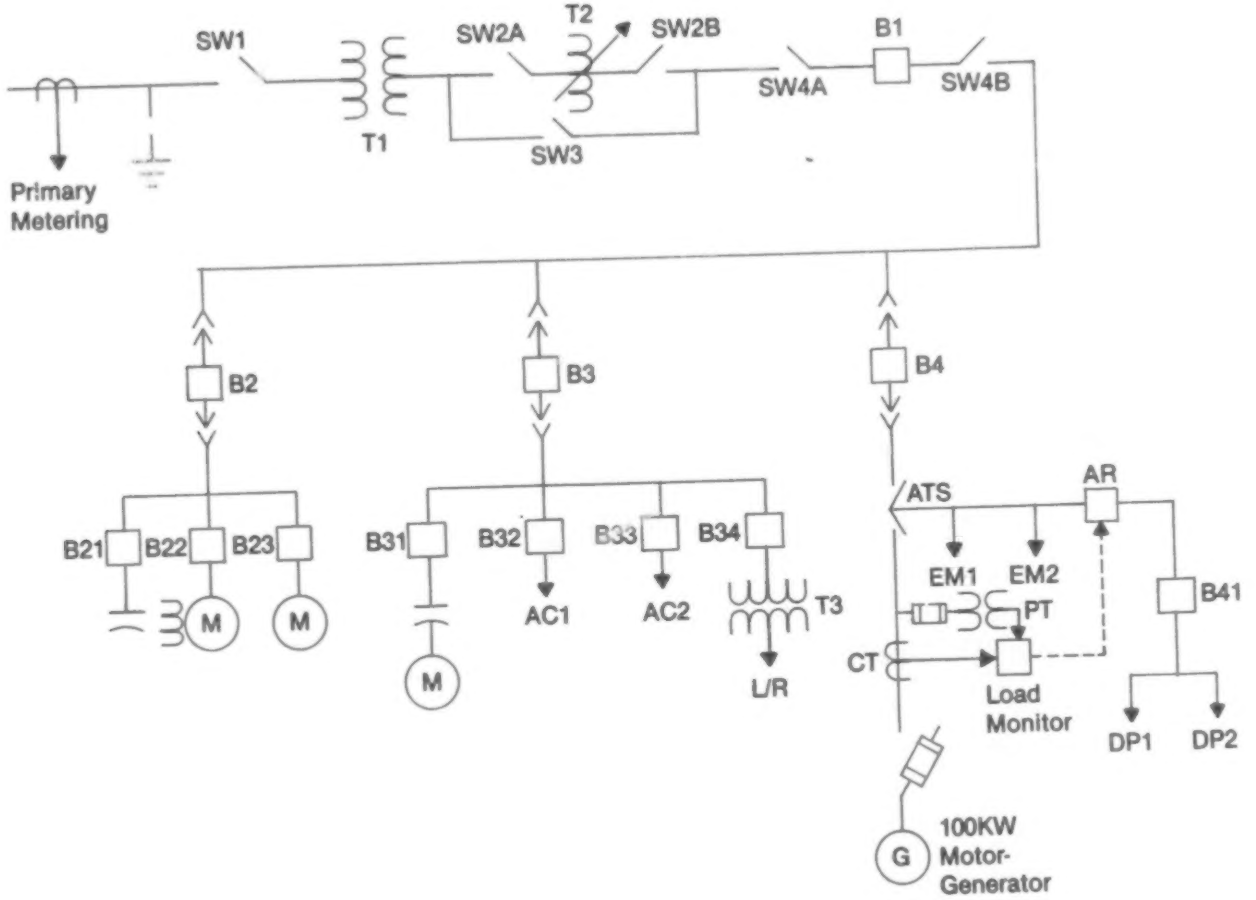
A technician will need to consult the plant's one-line diagram before planning an electrical addition of considerable power or when troubleshooting.

Refer to the following one-line diagram and the notes given below. Answer the questions concerning the diagram.

Notes:
SW — switch
B — breaker
M — motor
G — generator
PT — potential transformer
CT — current transformer
DP — data processing
AR — automatic relay
EM — emergency equipment
ATS — automatic transfer switch
AC — air conditioning
L/R — lighting and receptacles

ASSIGNMENT SHEET #2

One Line Diagram


SW1
T1
SW2A
T2
SW2B
SW3
B1
SW4A
SW4B
Primary Metering
B2
B3
B4
B21
B22
B23
M
M
B31
B32
B33
B34
M
AC1
AC2
T3
L/R
ATS
AR
EM1
EM2
PT
CT
Load Monitor
B41
DP1
DP2
G
100KW Motor-Generator

ASSIGNMENT SHEET #2

1. The ATS will connect to the generator if power fails. The generator will start automatically. In reference to the NEC articles 700-56 and 701-6, what is the purpose of breaker AR and the load monitor?

   ____

   ____

2. If the regulating transformer should fail, could the plant continue to operate?

   ____

3. Is there any power factor correction equipment in the plant?

   ____

4. Is there an overcurrent protective device at the generator output?

   ____

POWER FACTOR REGULATION
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

(NOTE: Answers are based on the 1985 edition of the NEC. Answers may change in subsequent editions.)

Assignment Sheet #1

1. Yes, 700, 700-56 and 701-6
2. Yes, 700, 700-12
3. Yes, 700, 700-26 or 230-95 or 701-17
4. Yes, 700, 701-5
5. 60 seconds, 700, 701-10
6. 460

Assignment Sheet #2

1. To disconnect the optional load if the generator becomes overloaded
2. Yes, there is a bypass switch around it
3. Yes, capacitors at B21 and B31
4. Yes, a fused disconnect

POWER FACTOR REGULATION
UNIT III

JOB SHEET #1 — MONITOR THE QUALITY OF AC POWER

I. Tools and materials

A. AC recording voltmeter or chart recorder connected to potential transformer

B. Clamp-on AC ammeter, at least 100 amperes capability

C. Oscilloscope, dual trace, at least 20 megahertz capability, with probes

D. Access to main electrical panels for the building, where 3ϕ power can be monitored under load

E. Multimeter with test leads

II. Procedure

CAUTION

This job sheet requires that you work close to heavy electrical wiring with potential to cause serious injury or death due to arcing, electrical shock, fires, or explosion. This work should not be done without your instructor's close supervision.

A. Connect a recording voltmeter to a 3ϕ power outlet to monitor the voltage for the duration of this job sheet

B. Set the chart feed rate very slow in order to conserve chart paper

C. Be certain that the chart recording meter is operating properly before you continue with this job sheet; ask your instructor to check it for proper connection and operation

D. Use the oscilloscope to monitor the power receptacles for 1ϕ 130 VAC as well as any 3ϕ 240 VAC outlets; look for transients and distortion of the waveforms

(NOTE: You will need to use a 10X probe and a very high vertical sensitivity setting.)

E. After observing the readings for several minutes, record your findings on the data sheet that follows this procedure under "Power disturbances noted"

(NOTE: Power transients, surges, or fluctuations are more likely to be seen when the building air conditioning, heating, or other large loads are turned on or off.)

F. Use the multimeter to measure each phase of a 3ϕ outlet; record your findings on the data sheet under "Voltage measurements"

JOB SHEET #1

G. Use the clamp-on ammeter at a high current; use distribution panel, breaker panel, or where main feeders can be monitored; record your findings on the data sheet under "Current"

CAUTION

While working near the distribution panels or high voltage switchgear, you should be under the instructor's close supervision.

H. Return to the voltage recorder; turn it off and disconnect it; note what you observe from the recording on the data sheet under "Recorded voltages"

I. Show your data sheet to the instructor

J. Put away tools and materials

JOB SHEET #1

AC POWER QUALITY
DATA SHEET

1. Power disturbances noted

   a. Transients ______________________________

   ____

   b. Voltage variations ______________________________

   ____

   c. Common-mode noise ______________________________

   ____

   d. Transverse-mode noise ______________________________

   ____

   e. Length of time observed ______________________________

2. Voltage measurements

   a. Phase A to B ______________________________

   b. Phase B to C ______________________________

   c. Phase C to A ______________________________

   d. Phase A to ground ______________________________

   e. Phase B to ground ______________________________

   f. Phase C to ground ______________________________

   g. The 3ϕ power circuit is which of the following? Circle three. Ask your instructor if you do not know.

      1) 3ϕ delta

      2) 3ϕ wye

      3) 240/480 volt (nominal)

      4) 480/277 volt (nominal)

    5) 120/240 volt (nominal)
    6) 3 wire
    7) 4 wire

3. Current
    a. Phase A ____________________
    b. Phase B ____________________
    c. Phase C ____________________
    d. Neutral or ground ____________________
    e. 4th wire if present ____________________

4. Recorded voltages — Maximum voltage variations
    a. Phase A minimum voltage ____________________
       maximum voltage ____________________
       deviation ____________________
    b. Phase B minimum voltage ____________________
       maximum voltage ____________________
       deviation ____________________
    c. Phase C minimum voltage ____________________
       maximum voltage ____________________
       deviation ____________________

POWER FACTOR REGULATION
UNIT III

JOB SHEET #2 — CONNECT POWER FACTOR CORRECTING CAPACITORS TO A MOTOR CIRCUIT

I. Tools and materials

A. 1.5 Kvar 3φ capacitor units, 2 each, rated at 240 VAC or more

(NOTE: Six, 60-μF capacitors may be used in lieu of the 3φ power factor capacitors. They must be rated for at least 240 VAC.)

B. Electric motor, 3φ , 3 HP, induction type, 240 volts

C. Power factor meter

D. Clamp-on ammeter

E. Multimeter

F. Motor starter, 3φ, 3 HP, 240 V

G. Fused disconnect, 3φ, 240 V, fused at 20 amperes

(NOTE: The fused disconnect may be disregarded if the lab has 3φ outlets which are properly fused with disconnecting means readily accessible.)

H. Wiring and apparatus to connect the motor starters to the power source through a fused disconnect and to connect the motor and capacitors as shown below

I. Start and stop pushbutton switches for motor starter

II. Procedure

A. Check the 3φ power source with the multimeter to be sure that it is approximately 230 VAC

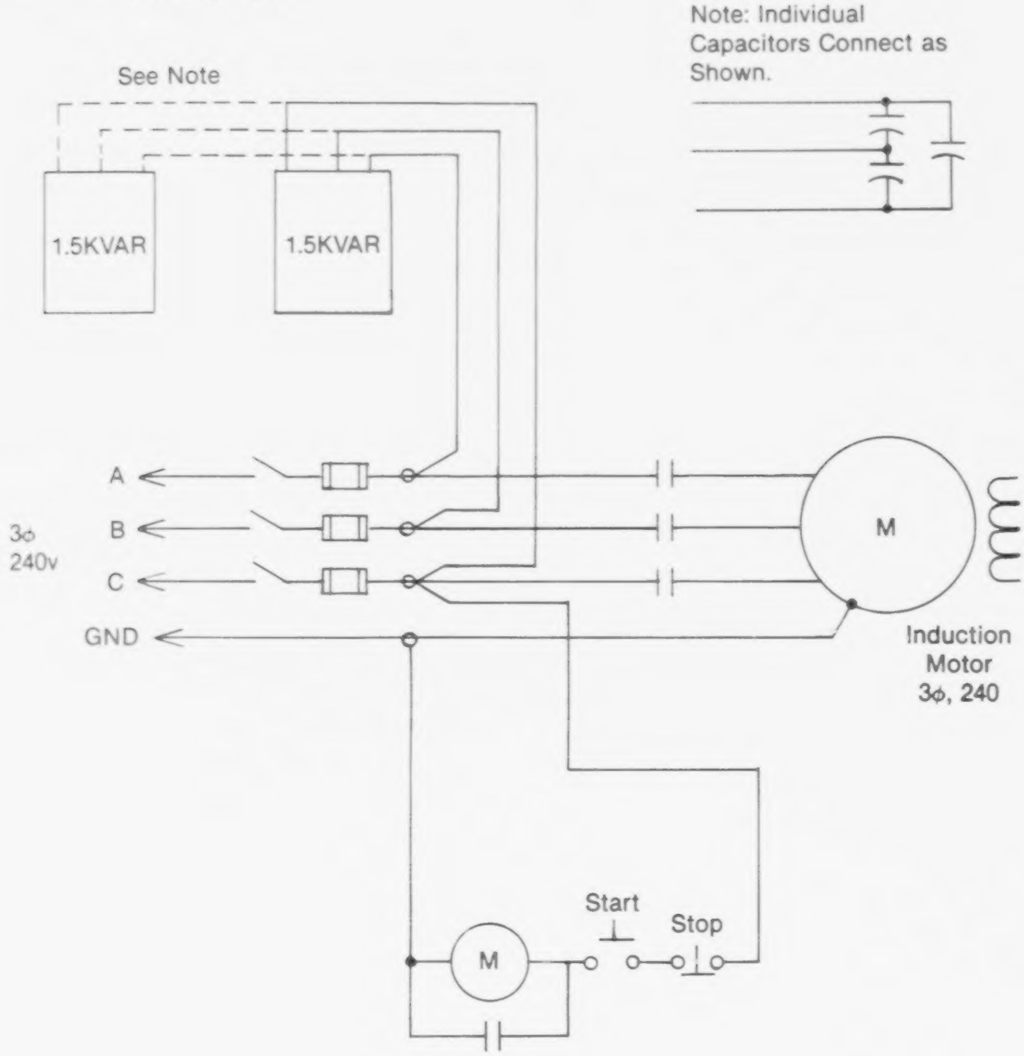
B. Turn off the 3φ power to the point at which you will connect this circuit

C. Make sure that the power is off by again measuring all three phases with the multimeter both between phases and to ground

D. Connect the motor, starter, disconnect, and start/ stop switches as shown in the following diagram (Figure 15)

JOB SHEET #2

FIGURE 15


Note: Individual
Capacitors Connect as
Shown.
See Note
1.5KVAR
1.5KVAR
A
B
C
3ϕ
240v
GND
M
Induction
Motor
3ϕ, 240
Start
Stop
M

E. Ask your instructor to check your work

JOB SHEET #2

F. Start the motor

G. Measure the current of each phase and record the values in the chart below

		Without Capacitors	One Set of Capacitors	Both Sets of Capacitors
Current	Phase A			
	B			
	C			
Volts	Phase A to B			
	B to C			
	C to A			
Power Factor				

H. Measure the voltages between phases and record in the chart

I. Use the power-factor meter to measure the power factor

J. Turn off the motor and disconnect the power

K. Connect one bank of capacitors to the circuit

L. Ask your instructor to check your work

M. Start the motor

N. Measure voltages, currents, and power factor again and record in the second column of the chart

O. Turn off the motor

P. Disconnect the power

Q. Connect the second bank of capacitors in parallel

R. Ask your instructor to check your work

S. Start the motor

T. Measure voltages, currents, and power factor again and record in the third column of the chart

(NOTE: You should notice a change in current as the power factor is changed.)

JOB SHEET #2

U. Show your chart of measurements to the instructor

V. Ask your instructor if you should continue on to Job Sheet #3 at this time or if you should dismantle the circuit

W. If you are not going to complete Job Sheet #3 at this time, put tools and materials away

POWER FACTOR REGULATION
UNIT III

JOB SHEET #3 — USE AN OSCILLOSCOPE TO DETECT TRANSIENTS IN AC POWER

I. Tools and materials

   A. Circuit assembled for Job Sheet #2 with or without power factor capacitors

   B. Oscilloscope with 10X probe, 20 megahertz or better resolution

II. Procedure

   A. Connect the oscilloscope probe to one motor lead

   B. Turn the vertical sensitivity to a high value such as 20 DIV

   C. Start and stop the motor and watch the oscilloscope waveform for voltage transients (spikes) or variations

   D. Switch the coupling to DC on the vertical amplifier input from the probe

   E. Start and stop the motor and watch for voltage fluctuations

   (NOTE: The surges and disruptions in AC power caused by large motors create the need for noise suppression equipment for computerized industrial equipment.)

   F. Discuss your results with the instructor

   G. Put away tools and materials

POWER FACTOR REGULATION
UNIT III

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with power factor regulation to their correct definitions. Write the numbers in the blanks provided.

______a. High voltage disturbance lasting less than 500 microseconds

______b. High voltage disturbance lasting longer than 500 microseconds

______c. Temporary high current condition on a line

______d. Circuit that impedes transients

______e. Device which protects power circuits from excessive current

______f. Electrical short-circuit to ground

______g. Any of the rapid firing devices such as SCRs, TRIACs, etc.

______h. Opposition to current or voltage changes due to inductance or capacitance

______i. All power dissipated by resistance in a circuit

______j. AC power stored as an electrical field in a capacitor or a magnetic field around an inductor

______k. Sum of true power and reactive power

______l. Percentage of true AC power compared to apparent AC power

______m. Result of 3ϕ power having two phases switched

______n. Controlling the power being used at particular times of the day

______o. Time of year or time of day when power usage is maximum

1. Ground fault
2. Apparent power
3. Voltage surge
4. Power factor
5. Transient (spike)
6. Thyristor
7. Peak demand
8. Reactive power
9. Suppressor
10. Phase-reversal
11. Current surge
12. Reactance
13. Demand control
14. True power
15. Overcurrent protection

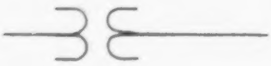
TEST

2. State meanings of abbreviations associated with power factor regulation. Write the correct meaning in the space provided.

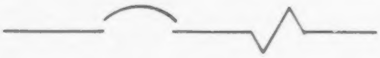
a. Var — ______________________
b. PF — ______________________
c. va — ______________________
d. Kvar — ______________________
e. EMI — ______________________
f. RFI — ______________________
g. CI — ______________________
h. GFP — ______________________
i. CB — ______________________
j. NEC — ______________________
k. Sec. — ______________________
l. OCR — ______________________
m. OCB — ______________________
n. ACR — ______________________
o. SCR — ______________________
p. GFI — ______________________
q. UPS — ______________________
r. EEPS — ______________________

3. Identify one-line diagram symbols associated with power factor regulation. Choose the correct term from the list below and write it in the space provided.

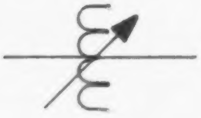
Voltage surge protection
Voltage regulating transformer
Potential transformer
Fused disconnect
Breaker with magnetic overload
Current source
Overcurrent protection (fuse)
Metering current transformer
Breaker
Breaker with thermal overload
Drawout type breaker
Capacitive diode (varactor)



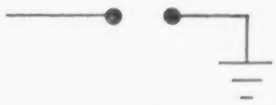
a. ______________________



b. ______________________

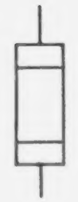


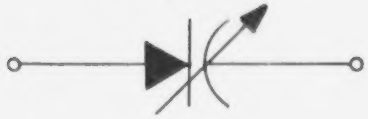
c. ______________________



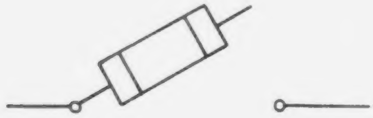
d. ______________________

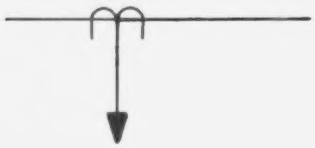
TEST



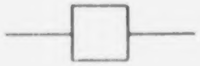


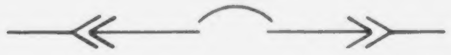
e. ____________________ f. ____________________



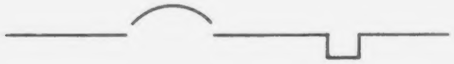


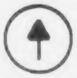
g. ____________________ h. ____________________





i. ____________________ j. ____________________





k. ____________________ l. ____________________

4. Describe types of electrical interference. Write your answers in the space provided.

   a. Electromagnetic interference (EMI) — ____________________
   ____
   ____

TEST

b. Radio frequency interference (RFI) — ______________________________

____

____

c. Conducted interference (CI) — ______________________________

____

____

d. Common-mode interference — ______________________________

____

____

5. Complete statements about considerations in power regulation. Write the correct word or words in the spaces provided.

Control of power factor

a. To ______________ costs of electrical power

b. To allow equipment to operate ______________

c. To conserve ______________

d. Requires balancing inductive and capacitive ______________

e. Transformers, motors, arc welders, and electromagnets ______________ the power factor

Control of voltage

f. May be required for ______________ or ______________ equipment to prevent damage or malfunction due to low voltage or high voltage conditions

g. May be required for ordinary equipment if ______________ voltage varies significantly

TEST

Protection from transients due to interference

h. To protect ________ -sensitive electronic circuitry

i. To ________ noise-generating machinery

j. May be required to ________ radio interference

Standby or emergency power

k. May be necessary to ________ life or ________ injury

l. May be necessary for medium to large computers to protect against loss of ________

m. May be necessary to prevent ________ to equipment, ________ of production, or loss of product material

n. May include generating equipment or ________ storage

Ground fault detection

o. May be required by national or local ________

p. Can protect wiring from extensive damage due to ________ to ground

Phase monitoring

q. To protect 3ϕ electrical equipment from operating with a loss of ________

r. To protect 3ϕ electrical equipment from phase ________

Energy demand control

s. May be required by electrical utility companies to reduce ________ ________

t. Can reduce an industry's electrical ________ substantially

TEST

6. Match power factor regulation test equipment to their correct uses. Write the number of the equipment beside its correct use.

______a. Used to scan electrical equipment for overloads and short circuits which create excessive heat

______b. Used to record voltage and current variations

______c. Used to measure power consumption

______d. Used to measure reactive power

______e. Used to indicate 3ϕ power phase relationship

______f. Used to detect high voltage leakage or shorts and to check ground connections

1. Strip-chart recorder
2. Power factor meter
3. Megohmeter (Megger)
4. Watt/Watt-hour meter
5. Phase sequence indicator
6. Infared thermometer

7. Match categories of auxiliary power systems to their characteristics. Write the number of the category in the space provided. A characteristic may apply to more than one type of system.

______a. Legally required by local, state, and federal codes

______b. Aid in exiting buildings

______c. May be used for computers, refrigeration, communications, industrial processes, or any user determined need

______d. Essential for human life and safety

______e. Must be used for lighting, ventilation, elevators, fire pumps, public communications, and dangerous industrial process control when threat to public is likely

______f. Must be used for heating, refrigeration, ventilation, lighting, and industrial process control where potential danger to public exists

______g. Provide for fire fighting, rescue, health hazard prevention, etc.

______h. Provide power to protect business or property from loss

______i. Required where large crowds may gather indoors

______j. Provide power where loss would damage equipment, interrupt production, or cause discomfort or inconvenience

1. Emergency systems
2. Legally required standby systems
3. Optional standby systems

TEST

(NOTE: Test items 8 through 10 list the assignment sheets and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

8. Determine Answers to Specific Questions by Consulting the National Electrical Code.

9. Analyze a One-Line Diagram.

10. Demonstrate the ability to

    a. Monitor the Quality of AC Power

    b. Connect Power-Factor Correcting Capacitors to a Motor Circuit

    c. Use an Oscilloscope to Detect Transients in AC Power

POWER FACTOR REGULATION
UNIT III

ANSWERS TO TEST

1. a. 5
   b. 3
   c. 11
   d. 9
   a. 15
   f. 1
   g. 6
   h. 12
   i. 14
   j. 8
   k. 2
   l. 4
   m. 10
   n. 13
   o. 7

2. a. Volt-ampere reactive power
   b. Power factor
   c. Volt-ampere
   d. Kilo-volt ampere reactive
   e. Electromagnetic interference
   f. Radio frequency interference
   g. Conducted interference
   h. Ground fault protection
   i. Circuit breaker
   j. National Electrical Code
   k. Section of NEC
   l. Oil circuit recloser
   m. Oil circuit breaker
   n. Automatic circuit recloser
   o. Silicon controlled rectifier
   p. Ground fault interrupter
   q. Uninterruptable power supply
   r. Emergency electrical power system

3. a. Potential transformer
   b. Breaker with magnetic overload
   c. Voltage regulating transformer
   d. Voltage surge protection
   e. Overcurrent protection (fuse)
   f. Capacitive diode (varactor)
   g. Fused disconnect
   h. Metering current transformer
   i. Breaker
   j. Drawout type breaker
   k. Breaker with thermal overload
   l. Current source

4. a. Electrical noise induced on an AC power line when a magnetic field momentarily envelops the AC power line
   b. Undesirable interference within the radio frequency spectrum (30 K - 30,000 MHz)
   c. Noise applied directly to power lines by loads
   d. Noise that appears between the terminals of a measuring circuit and ground

5. a. save
   b. cooler
   c. energy
   d. reactances
   e. lower
   f. critical, sensitive
   g. supply
   h. voltage
   i. isolate
   j. reduce
   k. protect, prevent
   l. data
   m. damage, loss
   n. battery
   o. codes
   p. arcing
   q. phase
   r. reversal
   s. peak demand
   t. costs

ANSWERS TO TEST

6. a. 6
   b. 1
   c. 4
   d. 2
   e. 5
   f. 3

7. a. 1, 2
   b. 1
   c. 3
   d. 1
   e. 1
   f. 2
   g. 2
   h. 3
   i. 1
   j. 3

8. Evaluated to the instructor's satisfaction.

9. Evaluated to the instructor's satisfaction.

10. Performance skills evaluated to the instructor's satisfaction.

DIGITAL COUNTING
AND
METERING CIRCUITS
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and analyze digital counting and metering circuits. The student will show the knowledge by completing assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms and definitions associated with digital counting and metering circuits to their correct definitions.
2. State meaning of acronyms, symbols, and abbreviations associated with digital counting and metering circuits.
3. Name logic and diagram symbols.
4. Complete statements about counters.
5. Identify digital display devices according to their characteristics.
6. Distinguish among types of segmented readouts according to their characteristics.
7. List parts of an industrial metering circuit and functions of each part.
8. Analyze logic diagrams.
9. Demonstrate the ability to
    a. Construct and analyze a counting and decoding circuit.
    b. Construct and analyze a binary counter.

DIGITAL COUNTING AND METERING CIRCUITS
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheet.

   C. Provide students with information, assignment, and job sheets.

   D. Discuss unit and specific objectives.

   E. Discuss information and assignment sheets.

   F. Demonstrate and discuss procedures outlined in the job sheets.

   G. Gather various metering devices from the lab and industry to demonstrate the variety of types of applications.

   H. Use transparencies to show the various counting circuits and metering circuits.

   I. Demonstrate the use of data reference manuals for I.C. devices. Discuss pin assignments, part numbers, voltage requirements, power dissipation, and compatibility, including TTL and CMOS devices.

   J. Administer test.

   K. Critique test.

   L. Reteach if necessary.

II. Instructional materials

   A. Objective sheet.

   B. Suggested activities.

   C. Information sheet.

   D. Transparency masters.

      1. TM #1 — Ripple Counter Timing Diagram

      2. TM #2 — Asynchronous and Synchronous Ripple Counters

      3. TM #3 — Synchronous Counters

SUGGESTED ACTIVITIES

4. TM #4 — D Flip-Flop Counter
5. TM #5 — Down Counter
6. TM #6 — Block Diagram of Industrial Metering Circuit
7. TM #7 — Simple Binary to Decimal Decoder
8. TM #8 — Seven-Segment Displays
9. TM #9 — Seven-Segment Displays (Con'd)

III. Unit references

A. Tokheim, Roger L. *Digital Electronics,* New York: McGraw-Hill, 1979.

B. Kershaw, John D. *Digital Electronics Logic and Systems,* North Scituate, Mass: Breton, 1983.

DIGITAL COUNTING AND METERING CIRCUITS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Asynchronous counter — Counter in which the clock or count pulses operate only the first flip-flop; each flip-flop is operated by the output of the preceding flip flop

(NOTE: Asynchronous counters are also referred to as ripple counters.)

B. Synchronous counter — Counter designed so that it has no ripple delay

(NOTE: Each flip-flop above the least significant bit is steered to change state by a decoded condition of the preceding flip-flops. The change of state of all flip-flops is caused by the same clock pulse.)

C. Modulus — Total number of 1 or 0 states available from a given counter

EXAMPLE: A counter containing four flip-flops has a modulus of 2.

D. Decimal counting unit (DCU) — Four-bit counter with logic circuits needed for a count of 0 through 9

(NOTE: A four-digit decimal counter would have four DCU's. DCU's are sometimes called decade counter.)

E. Down counter — Digital counter loaded with a present binary number; on each clock pulse, the count is decremented by 1

F. Decrement — To reduce sequentially by a uniform amount

G. Display — Visual readout of data

H. Light-emitting diode (LED) — Diode that glows when conducting a forward-bias current

I. Lamp test — A connection designed to test all or sets of indicators in a digital display by interrupting their normal function and causing all nondefective indicators to light

J. Hexadecimal readout — Display that produces the hexadecimal digits 0 through 9 and A through F

K. Seven-segment display — Readout that contains seven distinct segments; numbers or letters are displayed by lighting one or more of the segments

L. Decoder/Driver — Integrated circuit that can decode a binary number and produce an output capable of driving a display

M. LED dot matrix — Digital readout whose display is produced by lighting several LED dots

INFORMATION SHEET

II. Acronyms, symbols, and abbreviations

A. D/A — Digital to analog

B. A/D — Analog to digital

C. FF — Flip-flop

D. LSB — Least significant bit

E. MSB — Most significant bit

F. BCD — Binary coded decimal

G. Hex — Hexadecimal

H. LCD — Liquid crystal display

I. O — Binary zero or low

J. 1 — Binary one or high

K. N — Used to represent any whole number

EXAMPLE: Modulus N counter

L. CLR — Clear or reset

M. CLK — Clock

N. S — Set

O. R — Reset

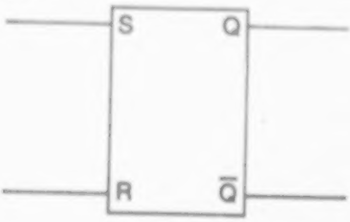
P. Q and $\overline{Q}$ — The two output labels for a given flip-flop

(NOTE: The symbols are pronounced "que" and "que not".)

III. Logic and diagram symbols (Figures 1-8)

A. Set/Reset flip-flop —

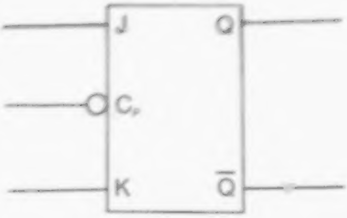
FIGURE 1



INFORMATION SHEET

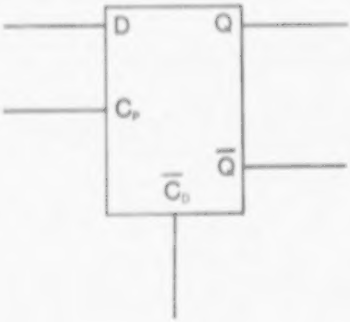
B. J-K flip-flop —

FIGURE 2


J
Q
C_P
K
$\overline{Q}$

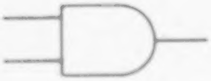
C. D flip-flop —

FIGURE 3


D
Q
C_P
$\overline{Q}$
$\overline{C}_D$

D. AND gate —

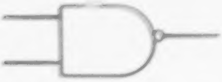
FIGURE 4



INFORMATION SHEET

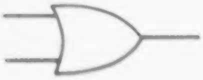
E. NAND gate —

FIGURE 5



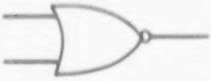
F. OR gate —

FIGURE 6



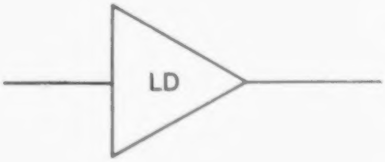
G. NOR gate —

FIGURE 7



H. Lamp driver —

FIGURE 8



IV. Counters

   A. Uses

      1. Count pulses

      2. Count time intervals

      3. Count events per unit of time

INFORMATION SHEET

B. Construction

1. Flip-flops for timed outputs

    a. R/S, J-K, or D flip-flops

    b. Modulus

    (NOTE: Each flip-flop in a counter has two possible states, 1 and 0 [set and reset]. The maximum number of possible combinations of 1 and 0 states is called the modulus. A counter composed of N flip-flops cannot have a modulus higher than 2^N states. For example, a counter with three flip-flops can have a modulus of 2^3 or 8.)

2. Decoder gates to decode flip-flop outputs

C. Types

1. Ripple counter (triggered counter) (Transparency 1)

    a. Asynchronous

    b. Two flip-flops can count from 0 through 3

    c. The first flip-flop will change state on the trailing edge of each clock pulse

    d. The second flip-flop will change state every time the first flip-flop changes from 1 to 0

    e. The AND gates act as the decoder

    f. Count to a number and reset

        1. Highest count is equal to 2^{N-1}

        2. OR and NOR gates used to reset the counter

        EXAMPLES: 74LS293 'Divide-by-N' IC counter

2. Synchronous counters (Transparency 2)

    a. Avoid delay difficulties of the asynchronous counter

    (NOTE: All flip-flops change state on the trailing edge of the clock pulse; therefore, no accumulation of delays exists between the LSB and the MSB.)

INFORMATION SHEET

b. J-K synchronous counter (Transparency 2 and 3)

1. Steered to toggle on receipt of a clock pulse if both J and K inputs are high
2. J and K lines are tied together

C. BCD counter (Transparency 3c)

1. Resets to zero after counting to nine
2. The output can be used to supply every tenth clock pulse to the clock line of the next counter

D. D flip-flop counter (Transparency 4)

1. $\overline{Q}$ output of preceding flip-flop connected to D input
2. Change occurs on the leading edge of each clock pulse

E. Down counter (Transparency 5)

1. Uses D flip-flops
2. Uses $\overline{Q}$ as input instead of Q
3. Preset input and count down to zero

EXAMPLE: SCL4404A I.C. 8-bit synchronous counter

V. Types of digital displays and their characteristics

A. Electro-mechanical devices

1. React slower because of gears and mechanisms
2. Usually employ solenoids
3. May be noisy
4. Eventually wear mechanically and fail
5. Require higher current to operate but no current to maintain a constant reading

EXAMPLE: Hourmeters

INFORMATION SHEET

B. LED segments

1. Visible in dark
2. Require less power than readout tubes
3. Require more power than LCD segments

C. LCD segments

1. Not visible in dark without source of light
2. Require less power than LED segments
3. Black segments against light background

   EXAMPLE: Totalizer

D. Dot matrix

1. Can display alphabetical and other characters in addition to numbers
2. May be fiber-optic LED or LCD dots

E. CRT screen

1. Can be shown in conjunction with graphic or waveform display
2. Character shapes, types, and sizes are virtually unlimited
3. Display requires computer software

   EXAMPLE: Computer monitor

VI. Types of segmented readouts

1. Incandescent (Transparency 8)
   - a. Uses thin metal element
   - b. Seven separate filament wires are used to supply the seven-segmented readout
2. Fluorescent lamp (Transparency 8)
   - a. Similar to a vacuum tube diode
   - b. Plate or anode coated with a phosphor that glows when bombarded by the electrons that are attracted to it
   - c. A negative potential applied to the control grid turns off all segments

INFORMATION SHEET

3. Neon and gas tubes (nixie tubes) (Transparency 9)
    a. Cold cathode diode gas tubes conduct electricity at a high voltage (usually 50 to 100 volts)
    b. Ten separate cathodes glow when conducting electricity
    c. The cathodes glow when conducting electricity
    d. Also used to form seven-segment readouts by constructing it with a single anode and seven separate cathodes to form the seven segments 0 through 9 and A through G
4. Light Emitting Diodes (LED) (Transparency 9)
    a. A semi-conductor diode that produces light emission in its forward bias state
    b. The seven-segment LED can be either common cathode or common anode
    c. LED's are inexpensive and require low voltages to operate (5 VDC typical)

VII. Parts and functions of industrial metering circuits (Transparency 6)

A. Input buffer amplifier
1. Isolates circuitry from voltage variations, current loops, surges, etc.
2. May contain wave-shaping circuitry to square-up distorted waves
3. May contain filtering to remove high-frequency transients
4. Provides voltage output compatible to counter input requirements
5. Input may be a signal from a field mounted transducer or generator

B. Controls
1. Allows for reset, start/stop, and other basic functions
2. May control buffer amp to provide sensitivity adjustment to discriminate against low-level noise
3. May contain circuitry to select counting pulses per unit of time and reset or accumulate counts
4. May allow for retaining the highest count during a period of time

INFORMATION SHEET

EXAMPLE: To measure maximum flow rate before a "safety-trip" a pump may be "overrun" while metering and the last (highest) rate retained for verification.

C. Counter

1. May be any of the various types of counter circuits
2. May contain provisions for "programming" by DIP switches, PROMS, etc. to divide the input counts to give corrected rates, to calibrate or compensate for transducer variance, etc.
3. Output may be in binary code or single pulse for each unit
4. Comprised of flip-flops primarily

D. Decoder (Transparency 7)

1. Puts output into usable form by converting
2. May automatically reset the counter for a certain end count
3. Comprised primarily of gates

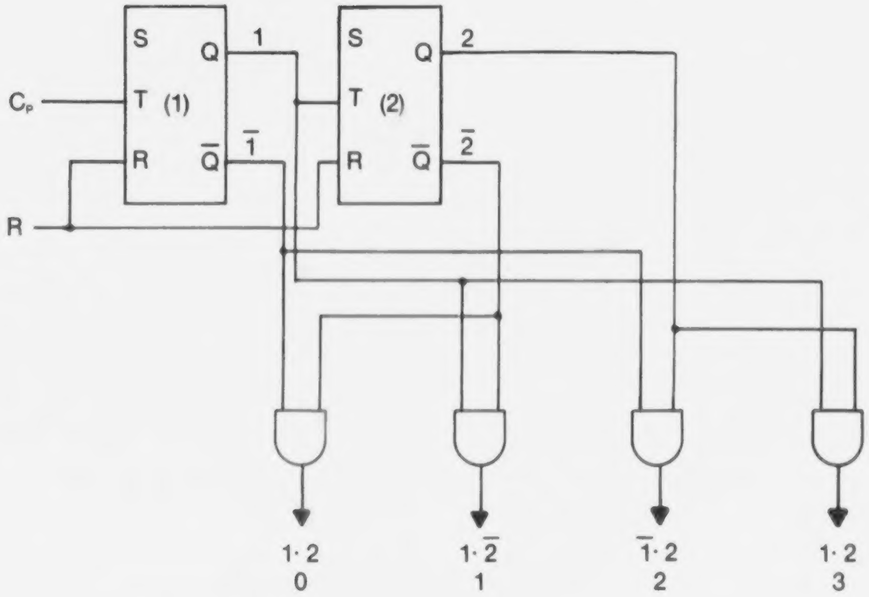
E. Driver amplifier

1. Supplies power to the display
2. Converts from low level logic to levels required by the display
3. Comprised of IC operational amplifiers or discrete transistor amplifiers

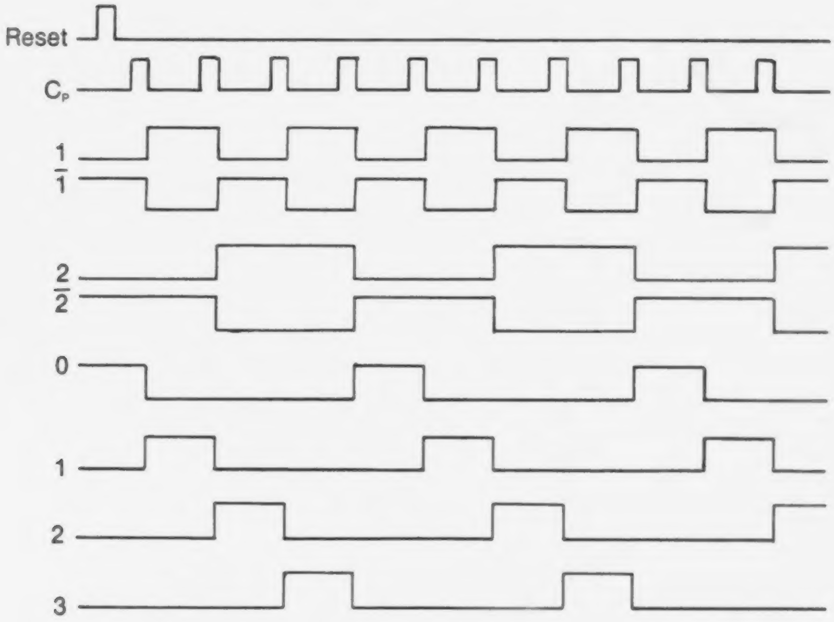
F. Display

1. May be electronic or electromechanical
2. Shows readout of circuit

Ripple Counter

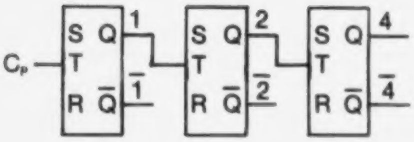

S
Q
1
T (1)
$\overline{Q}$
$\overline{1}$
R
S
Q
2
T (2)
R
$\overline{Q}$
$\overline{2}$
C_P
R
1· 2
0
1· $\overline{2}$
1
$\overline{1}$· 2
2
1· 2
3

Timing Diagram



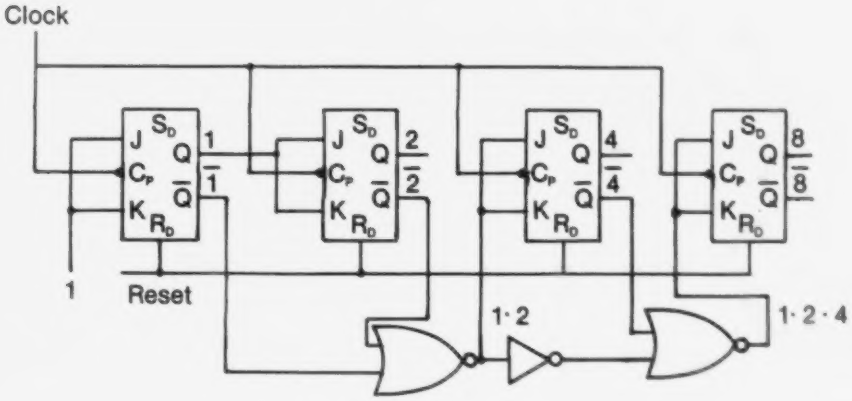
Ripple Counters

Asynchronous


C_P
S
T
R
Q
$\overline{Q}$
1
$\overline{1}$
2
$\overline{2}$
4
$\overline{4}$

1	2	4	Dec.
0	0	0	0
1	0	0	1
0	1	0	2
1	1	0	3
0	0	1	4
1	0	1	5
0	1	1	6
1	1	1	7

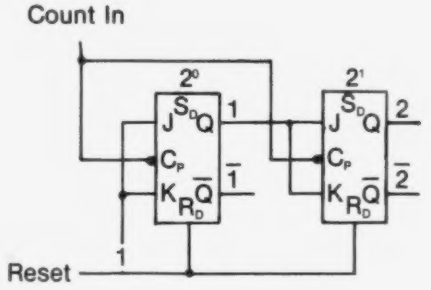
Synchronous


Clock
J
C_P
K
S_D
R_D
Q
$\overline{Q}$
1
$\overline{1}$
2
$\overline{2}$
4
$\overline{4}$
8
$\overline{8}$
1
Reset
1·2
1·2·4

Synchronous Counters

(a)

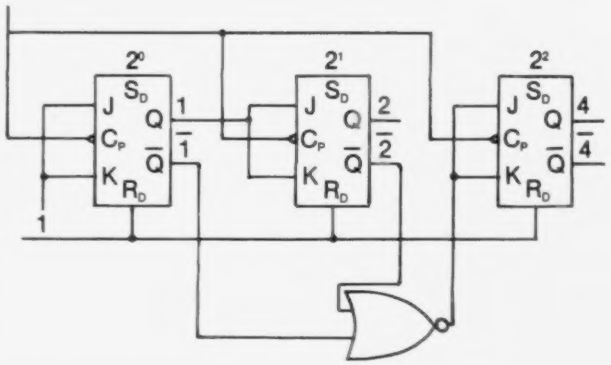
C_P NO.	2^0	2^1
0	0	0
1	▨ 1	0
2	0	1
3	▨ 1	▨ 1
4	0	0
5	▨ 1	0
6	0	1
7	▨ 1	▨ 1


Count In
2^0
2^1
J
S_D
Q
C_P
K
R_D
$\overline{Q}$
1
$\overline{1}$
2
$\overline{2}$
1
Reset

▨ Condition That Should Steer the Next Higher Flip-Flop to Toggle on the Next Clock Pulse

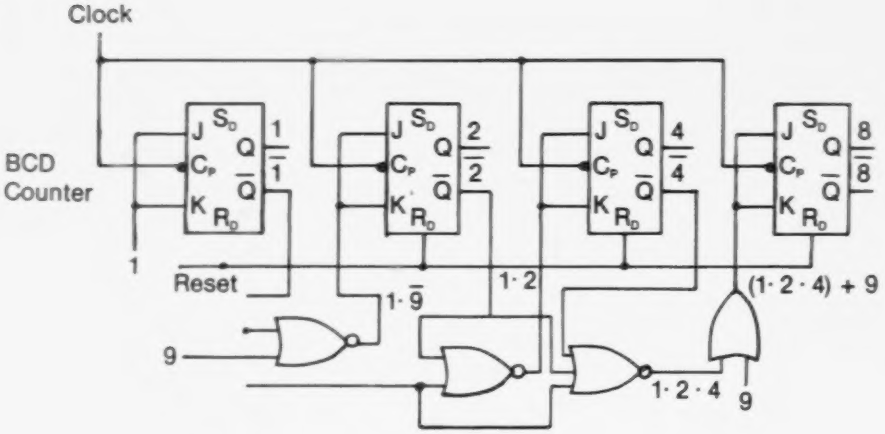
(b)

C_P NO.	2^0	2^1	2^2
0	0	0	0
1	▨ 1	0	0
2	0	1	0
3	▨ 1	▨ 1	0
4	0	0	1
5	▨ 1	0	1
6	0	1	1
7	▨ 1	▨ 1	▨ 1

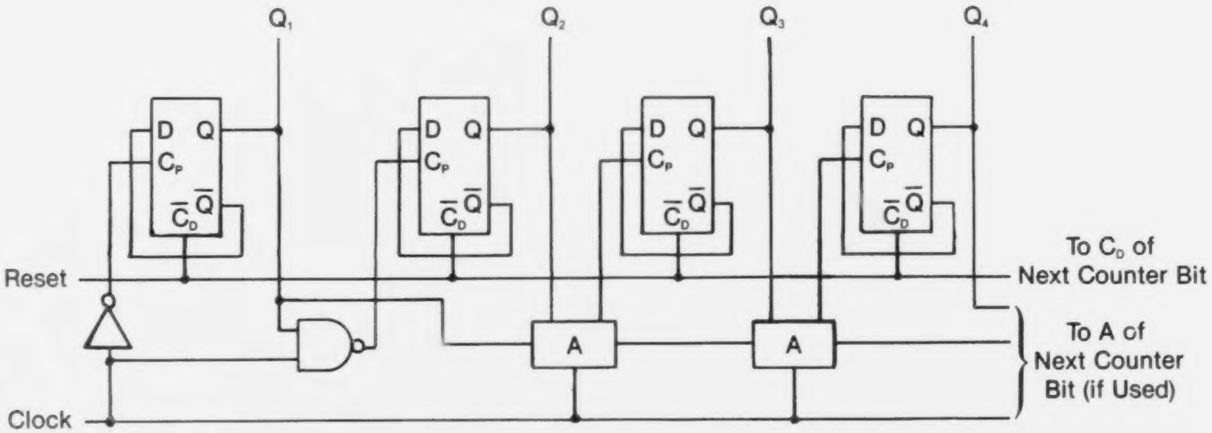

2^0
2^1
2^2
J
S_D
Q
C_P
K
R_D
$\overline{Q}$
1
$\overline{1}$
2
$\overline{2}$
4
$\overline{4}$
1

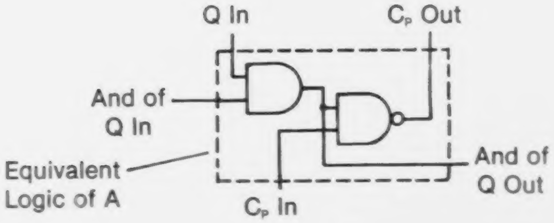
▨ Condition That Must Steer the Next Higher Flip-Flop to Toggle on the Next Clock Pulse

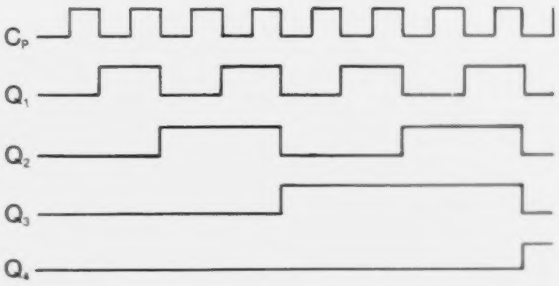
(c)


Clock
BCD Counter
J
S_D
Q
C_P
K
R_D
$\overline{Q}$
1
$\overline{1}$
2
$\overline{2}$
4
$\overline{4}$
8
$\overline{8}$
1
Reset
$1 \cdot \overline{9}$
$1 \cdot 2$
$(1 \cdot 2 \cdot 4) + 9$
9
$1 \cdot 2 \cdot 4$
9

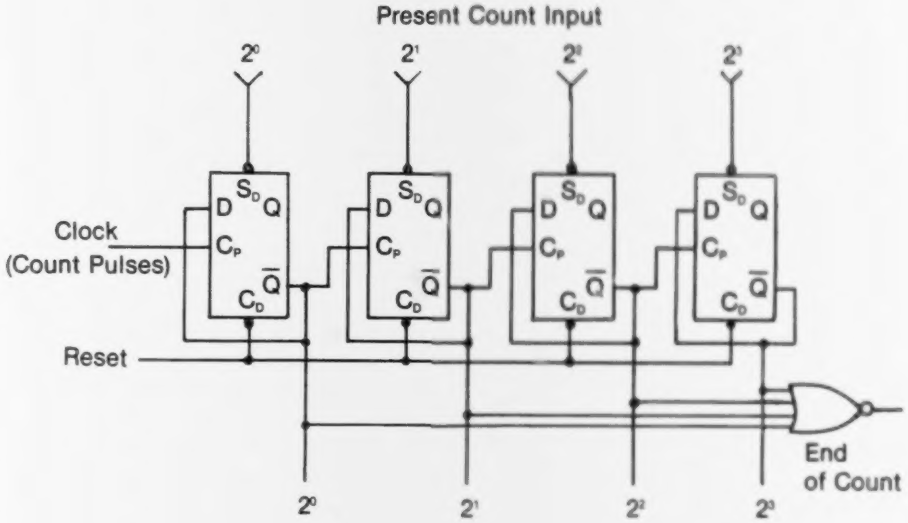
'D' Flip-Flop Counter


Q1
Q2
Q3
Q4
D
Q
CP
CD
Q̄
Reset
Clock
A
A
To CD of Next Counter Bit
To A of Next Counter Bit (if Used)

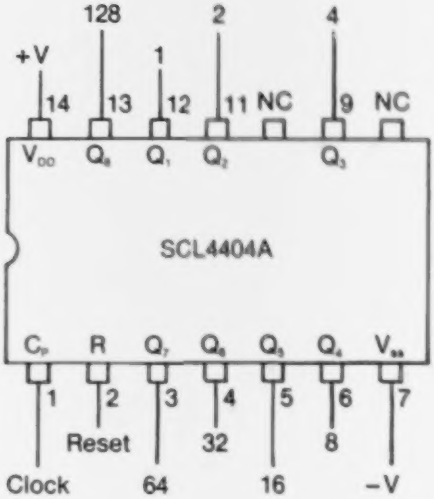

Q In
CP Out
And of Q In
Equivalent Logic of A
CP In
And of Q Out



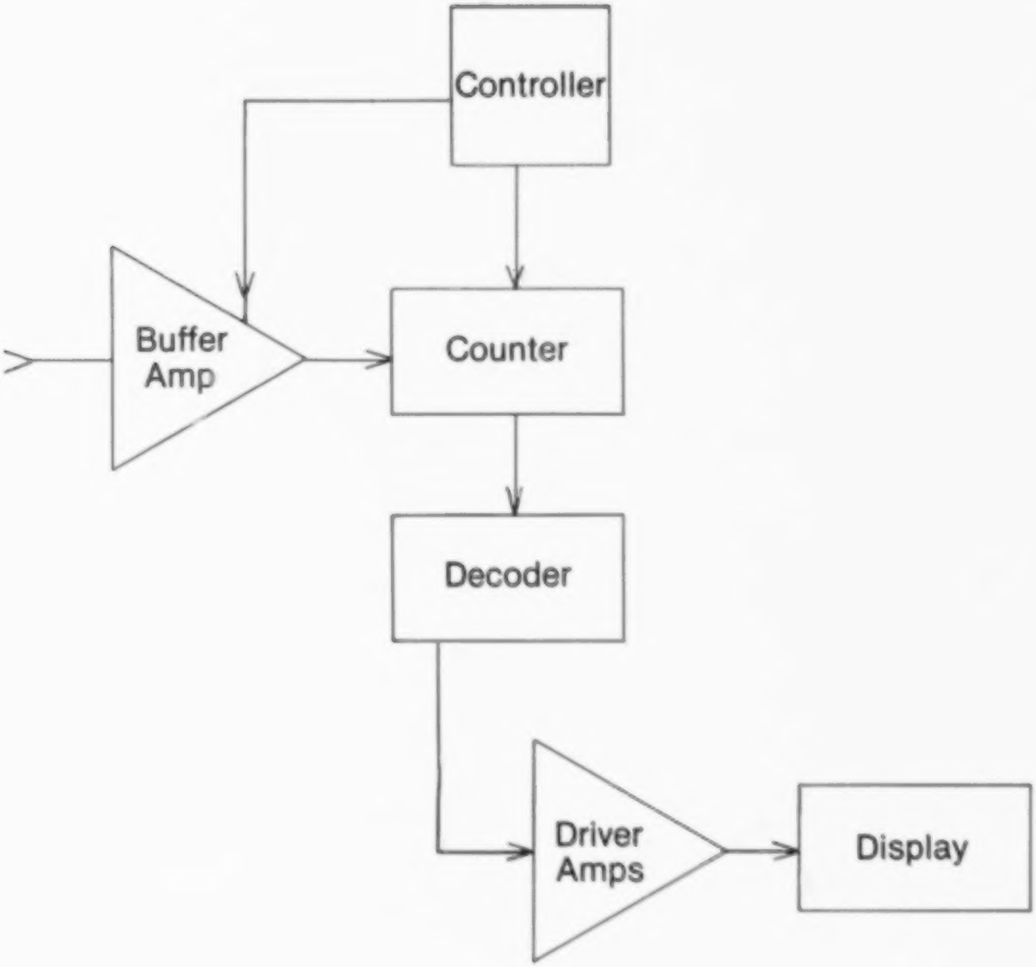
Down Counter


Present Count Input
2⁰
2¹
2²
2³
D
S_D
Q
C_P
Q̄
C_D
Clock
(Count Pulses)
Reset
End
of Count
2⁰
2¹
2²
2³

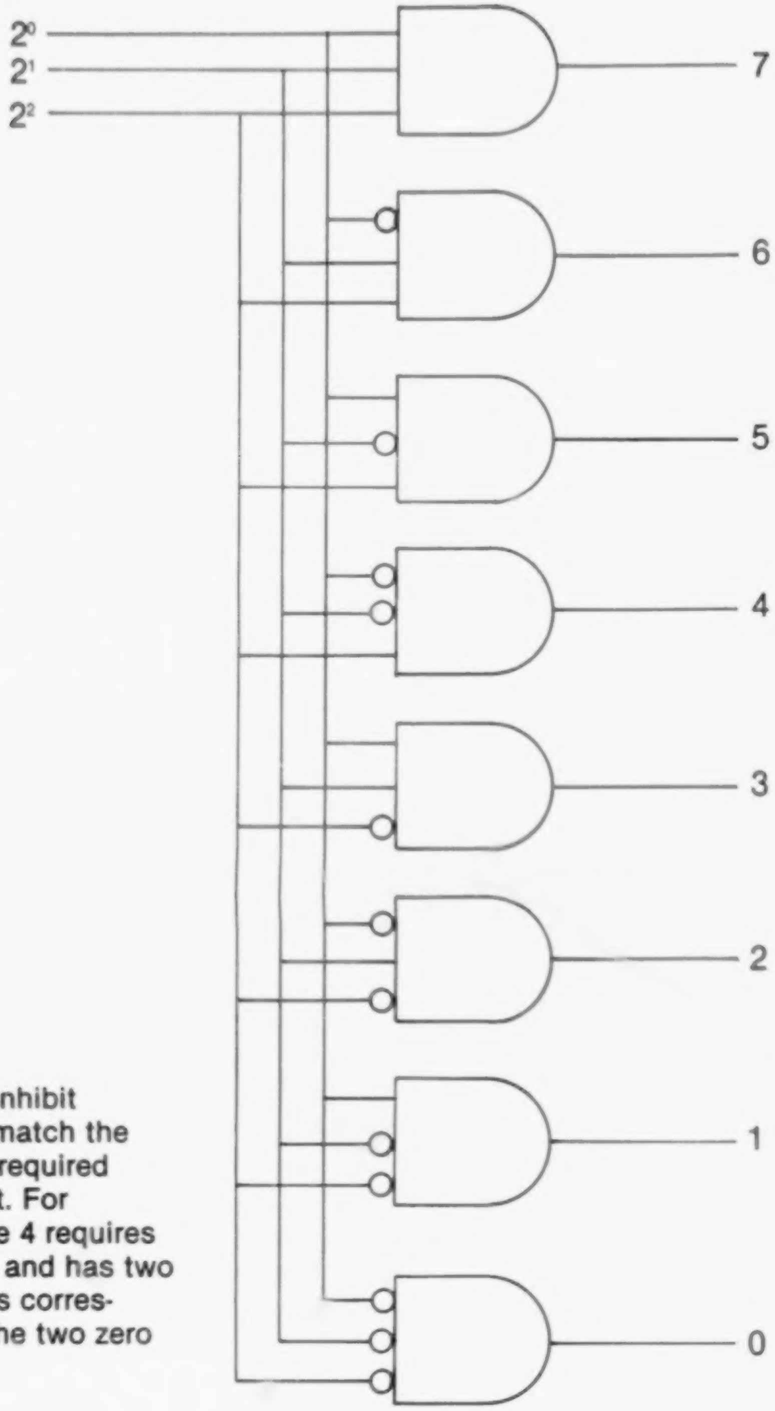
I.C. 8-Bit Synchronous Counter (CMOS)


128
2
4
+V
1
14
13
12
11
NC
9
NC
V_DD
Q_8
Q_1
Q_2
Q_3
SCL4404A
C_P
R
Q_7
Q_6
Q_5
Q_4
V_SS
1
2
3
4
5
6
7
Reset
32
8
Clock
64
16
−V

Block Diagram of Industrial Metering Circuit


Controller
Buffer Amp
Counter
Decoder
Driver Amps
Display

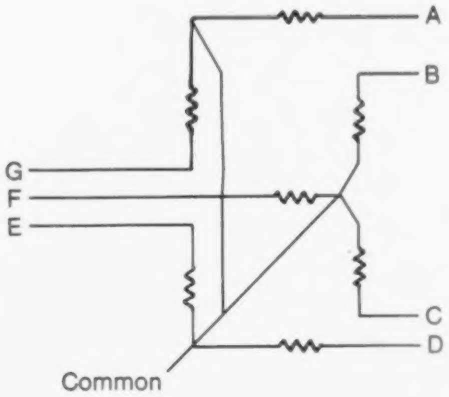
Simple Binary to Decimal Decoder



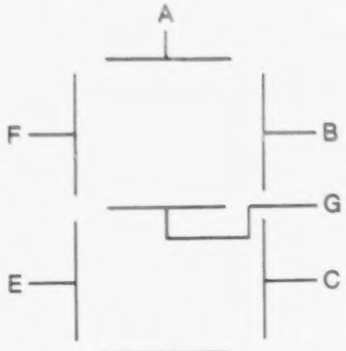
(NOTE: The inhibit gate inputs match the binary code required for an output. For example gate 4 requires an 001 input and has two inhibit circles corresponding to the two zero inputs.)

Seven-Segment Displays

Incandescent

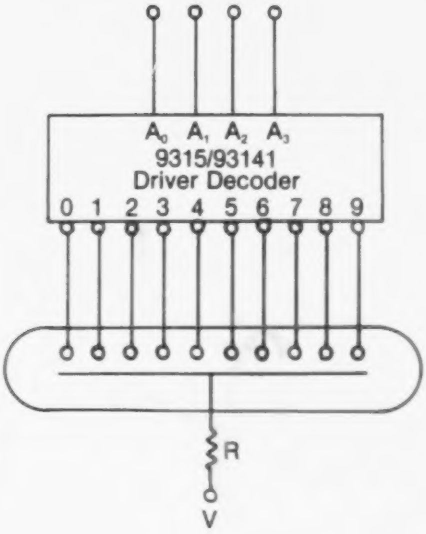

A
B
G
F
E
C
D
Common

Fluorescent

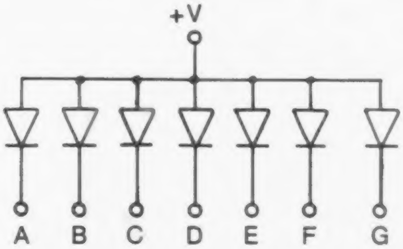


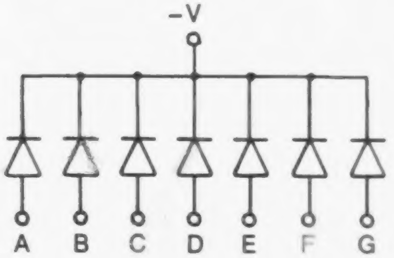
Seven-Segment Displays
(Continued)

Neon and Other Gas Tubes


A_0 A_1 A_2 A_3
9315/93141
Driver Decoder
0 1 2 3 4 5 6 7 8 9
R
V

Light-Emitting Diode (LED)





DIGITAL COUNTING AND METERING CIRCUITS
UNIT IV

ASSIGNMENT SHEET #1 — ANALYZE LOGIC DIAGRAMS

NAME ______________________________ SCORE ______________

In order to effectively troubleshoot logic circuitry a technician must be able to analyze the binary levels and outputs resulting from various input combinations. Assume the following circuitry is positive logic, e.g. 1 = high, 0 = low; a high represents an active level and a low is an inactive.

There are several methods used to analyze logic circuits. Basically, a diagram is used to mark initial conditions and to follow the changes through to output. The guidelines below will help you in the analysis process.

A. Select an appropriate method for marking binary levels at component inputs and outputs, using either 1 and 0 or H and L

   1. Project transparency of diagram onto a chalkboard and use chalk

   2. Overlay the diagram with mylar or clear plastic sheet and use grease pencil or erasable pen

   3. Place diagram on corkboard and use pins for active inputs and remove pins for inactive inputs

   4. Use soft lead pencil and clean eraser

   (NOTE: Marking directly onto equipment diagrams is not usually an accepted practice since the diagrams will eventually be damaged and difficult to read.)

B. Mark initial conditions

   1. In actual troubleshooting situations conditions will be determined by using a logic probe or logic analyzer

   2. When analyzing counters assume an initial count of zero and mark flip-flops accordingly

C. Mark input levels

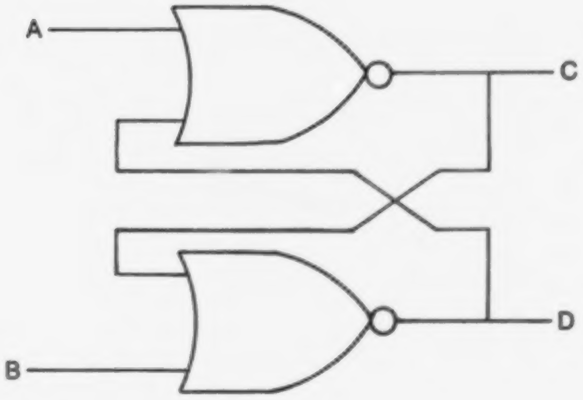
D. Transfer inputs into outputs for each logic device and carry those outputs to the next device

E. Erase and change feedback line levels as they change due to input changes and flip-flop toggle actions

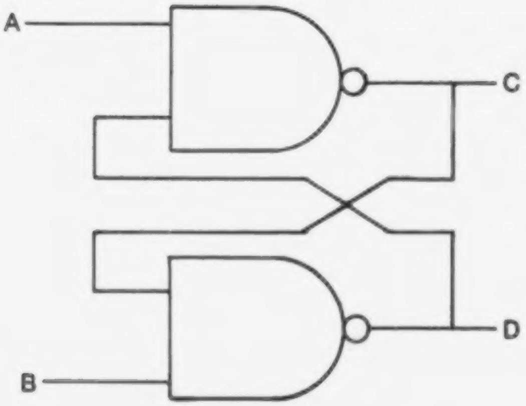
Use the guidelines above to analyze the circuits below and answer the accompanying questions. Show your work to your instructor or discuss in class.

ASSIGNMENT SHEET #1

1. Are the two circuits shown below functionally different? (Do they produce different outputs for identical inputs?)



CIRCUIT 1



CIRCUIT 2

ASSIGNMENT SHEET #1

2. Complete the truth tables below for circuits. Use 1, 0, or ?.

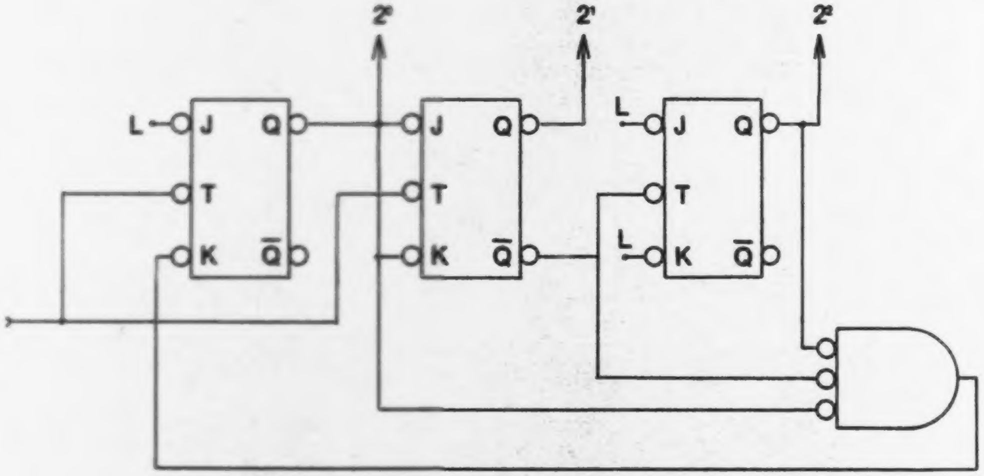
a.

CIRCUIT 1			
A	B	C	D
0	0		
0	1		
1	0		
1	1		

b.

CIRCUIT 2			
A	B	C	D
0	0		
0	1		
1	0		
1	1		

3. Analyze the following counter and complete the table. Assume a positive to negative transition will trigger the flip-flops. Assume positive logic, e.g. H = active = 1. Be careful to consider the inversions at inputs and outputs of the flip-flops.


2^0
2^1
2^2
L
J
Q
T
K
$\overline{Q}$
J
Q
T
K
$\overline{Q}$
L
J
Q
T
L
K
$\overline{Q}$

ASSIGNMENT SHEET #1

Count	2^0	2^1	2^2	Decimal Equivalent
0	L	L	L	0
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

4. Is the counter shown above a modulus counter?

____

5. If the circuit was interpreted as negative logic, e.g. L = 1, what would the decimal equivalent at the outputs be?

____

ASSIGNMENT SHEET #1

6. Assume that the trigger inputs to the flip-flops react to positive transitions instead of negative transitions. Complete the truth table below.

Count	2^0	2^1	2^2	Decimal Equivalent
0	L	L	L	0
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

DIGITAL COUNTING AND METERING CIRCUITS
UNIT IV

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1

1. Yes

2. a.

A	B	C	D
0	0	*	*
0	1	1	0
1	0	0	1
1	1	0	0

b.

A	B	C	D
0	0	1	1
0	1	0	1
1	0	1	0
1	1	*	*

*undefined

3. 1 H H H 7

2 L H H 6

3 H L H 5

4 L L H 4

5 H H L 3

6 L H L 2

7 L L L 0

8 H H H 7

9 L H H 6

10 H L H 5

ANSWERS TO ASSIGNMENT SHEET

4. Yes (a modulus 7 counter)

5. 7, 0, 1, 2, 3, 4, 5, 7, 0, 1, 2

6. 1 H H L 3

   2 L H L 2

   3 L L H 4

   4 H H H 7

   5 L H H 6

   6 H L L 1

   7 L L L 0

   8 H H L 3

   9 L H L 2

   10 L L H 4

DIGITAL COUNTING AND METERING CIRCUITS
UNIT IV

JOB SHEET #1 — CONSTRUCT AND ANALYZE A COUNTING AND DECODING CIRCUIT

I. Equipment and materials

  A. Type 74154 24-pin IC decoder

  B. Type 7493 16-pin IC counter

  C. Type 7400 16-pin IC

  D. Breadboard

  E. 5-volt DC bench power supply

  F. Data manual (reference for the ICs required above)

  G. IC test clip for 24-pin IC

  H. Pushbutton switch, miniature, SPST, N.O.

  I. Resistor, 1/4 W, 150 ohm

  J. Resistor, 1/4 W, 10 Kohm

  K. Capacitor, 10 μ

  L. Logic probe

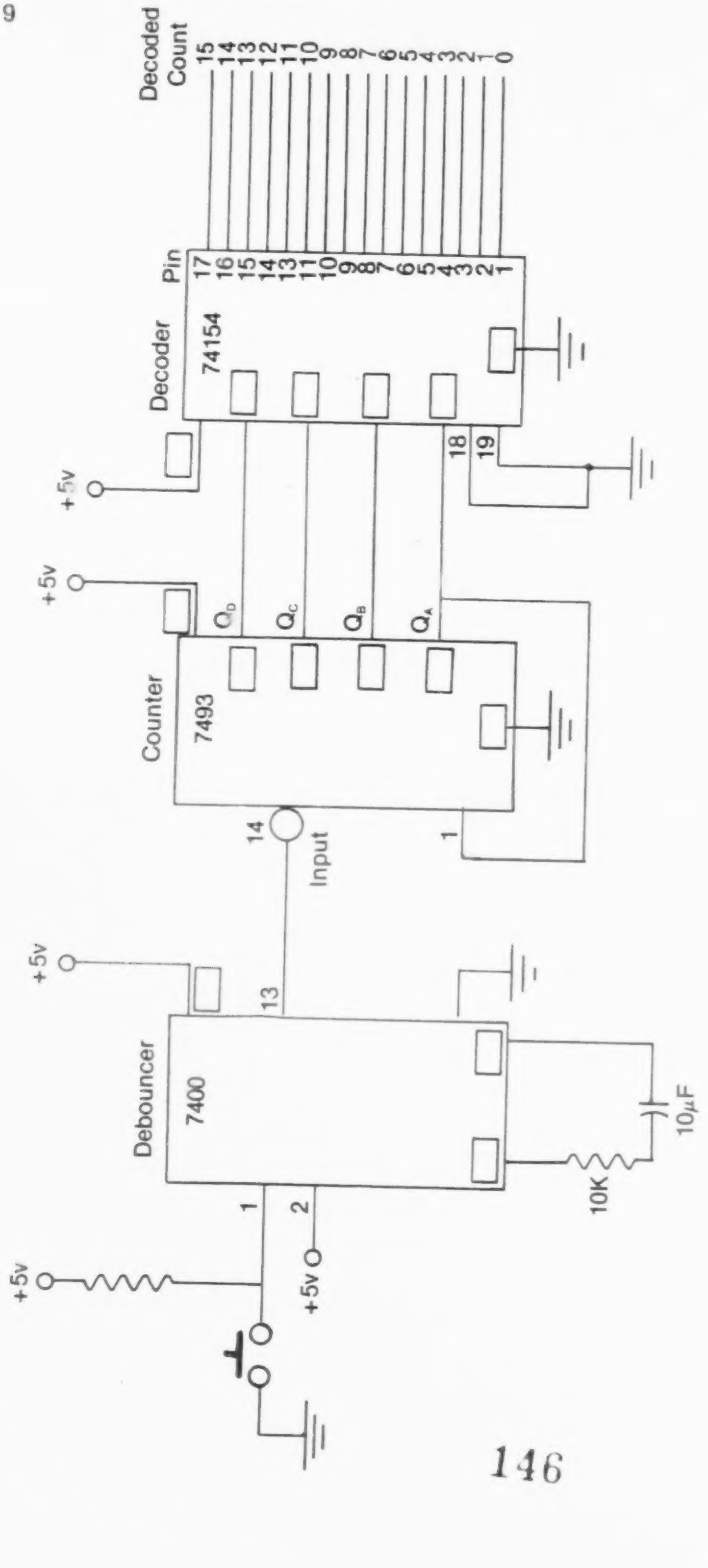
II. Procedure

  A. Consult the reference manual to find the pin arrangements of the ICs

  B. Determine the proper pin connections to construct the following circuit; some pin numbers are given; write the other pin numbers in the small blocks next to the pins (Figure 9)

JOB SHEET #1

FIGURE 9


Decoded Count
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Pin
17
16
15
14
13
11
10
9
8
7
6
5
4
3
2
1
Decoder
74154
18
19
+5v
+5v
Q_D
Q_C
Q_B
Q_A
Counter
7493
14
Input
1
+5v
13
Debouncer
7400
10K
10μF
1
2
+5v
+5v

JOB SHEET #1

C. Construct the circuit on the breadboard but do not connect the power supply

D. Ask your instructor to check your circuit

E. Once the circuit construction has been checked, connect the power supply

F. Connect the IC test clip to the 7493 counter

G. Push button until the four output lines read low (logic zero)

H. Connect the IC test clip to the 74154 IC

I. Push the button once and notice that the decoder will indicate a reading on only the #1 line (pin 2)

J. Push the button and for each count verify that the decoder will indicate a reading on only one line

K. Complete the truth table below as indicated by the first entries

Count	Q_A	Q_B	Q_C	Q_D	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				

JOB SHEET #1

(NOTE: If 10, 11, 12, 13, 14, and 15 were labeled A, B, C, D, E, and F the decoder could be called a binary to hexadecimal decoder.)

L. Show your results to your instructor

M. Put tools and materials away

DIGITAL COUNTING AND METERING CIRCUITS
UNIT IV

JOB SHEET #2 — CONSTRUCT AND ANALYZE A BINARY COUNTER

I. Tools and equipment

   A. 2 - 7476 dual J-K flip-flops

   B. 1 - 7411 triple AND I.C.

   C. 1 - Light-emitting diode

   D. 1 - SPDT switch

   E. 1 - Logic probe (optional) or multimeters

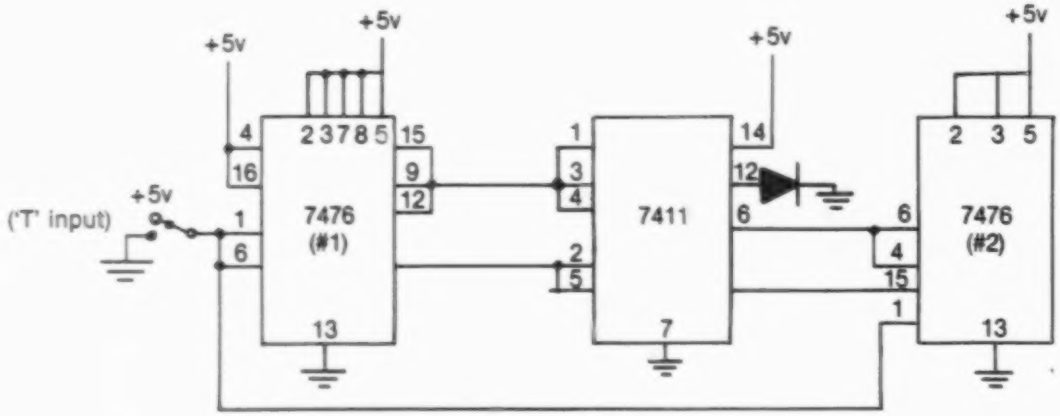
   F. +5vdc power source

II. Procedure

   A. Connect the circuit as shown below (Figure 10)

   (NOTE: The J-K flip-flops are connected as toggle flip-flops)

FIGURE 10



+5v
+5v
+5v
+5v
+5v
('T' input)
4
16
1
6
2 3 7 8 5
15
9
12
7476
(#1)
13
1
3
4
2
5
7411
7
14
12
6
6
4
15
1
2 3 5
7476
(#2)
13

   B. Have your instructor check the circuit

   C. Verify input with the logic probe or measure close to +5 vdc with a multimeter at pin 1 of the first J-K flip-flop

   (NOTE: The toggle input to the first flip-flop is always one or high.)

JOB SHEET #2

D. Create pulses by throwing the SPDT switch to 5V then to ground while observing pin 15 of the first 7476 flip-flop; write the reaction of the meter or logic probe below

____

E. Continue throwing the switch until the LED glows

(NOTE: This may take up to eigth pulses.)

F. Input eight clock pulses and write what happens to the LED

____

G. Pulse the circuit until the LED illuminates again

H. Attach a logic probe or meter to pin 11 of the first 7476; how many input pulses are needed to cause a change in the probe or meter?

____

I. Repeat step E using pin 15 of the second 7476; how many inputs are needed for the change?

____

(NOTE: The Q output of the first flip-flop changes state after every input pulse, the second flip-flop on every other input, and the third flip-flop on every fourth input. The circuit output is high for the length of one input pulse after eight inputs have been received. This circuit is often referred to as ripple counter because of this effect.)

J. Show your job sheet and results to the instructor

K. Put all tools and equipment in their proper place and clean up the work area

DIGITAL COUNTING AND METERING CIRCUITS
UNIT IV

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with digital counting and metering circuits to their correct definitions. Write the number of the term beside its correct definition.

______a. Counter in which the clock or count pulses operate only the first flip-flop; each flip-flop is operated by the output of the preceding flip-flop

______b. Counter designed so that it has no ripple delay

______c. Total number of 1 or 0 states available from a given counter

______d. Four-bit counter with logic circuits needed for a count of 0 through 9

______e. Digital counter loaded with a preset binary number; on each clock pulse, the count is decremented by 1

______f. To reduce sequentially by a uniform amount

______g. Visual readout of data

______h. Diode that glows when conducting a forward-bias current

______i. A connection designed to test all or sets of indicators in a digital display by interrupting their normal function and causing all nondefective indicators to light

______j. Display that produces the hexadecimal digits 0 through 9 and A through F

______k. Readout that contain seven distinct segments; numbers or letters are displayed by lighting one or more of the segments

______l. Integrated circuit that can decode a binary number and produce an output capable of driving a display

______m. Digital readout whose display is produced by lighting several LED dots

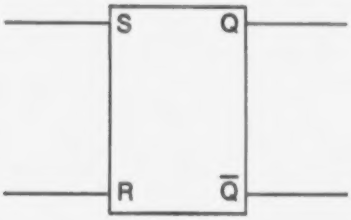
1. Lamp test
2. Modulus
3. Seven-segment display
4. Down counter
5. Asynchronous counter
6. Hexadecimal readout
7. LED dot matrix
8. Synchronous counter
9. Decimal counting unit
10. Decoder/Driver
11. Light-emitting diode
12. Display
13. Decrement

TEST

2. State meaning of acronyms, symbols, and abbreviations associated with digital counting and metering circuits. Write the correct meaning in the space provided.

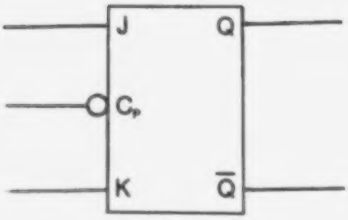
   a. D/A — ______________________________
   b. A/D — ______________________________
   c. FF — ______________________________
   d. LSB — ______________________________
   e. MSB — ______________________________
   f. BCD — ______________________________
   g. HEX — ______________________________
   h. LCD — ______________________________
   i. 0 — ______________________________
   j. 1 — ______________________________
   k. N — ______________________________
   l. CLR — ______________________________
   m. CLK — ______________________________
   n. S — ______________________________
   o. R — ______________________________
   p. Q and $\overline{Q}$ — ______________________________

3. Label logic and diagram symbols associated with digital counting and metering circuits. Write the correct name in the space provided.

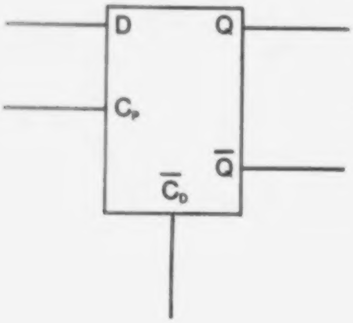


   a. ______________________________

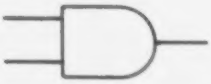
TEST


J
Q
C_p
K
$\overline{Q}$

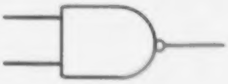
b. ______________________________


D
Q
C_p
$\overline{Q}$
$\overline{C}_D$

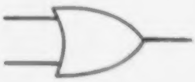
c. ______________________________



d. ______________________________

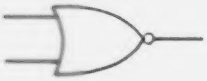


e. ______________________________

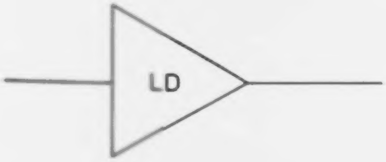


f. ______________________________

TEST



g. ____



h. ____

4. Complete statements about counters. Write the missing word or term in the blanks of the statements below.

   a. Counters can be used to count ____________, ____________ intervals, or ____________ per unit of time.

   b. Counters can be constructed from ____________, ____________, ____________ flip-flops.

   c. Decoder gates are used to decode flip-flop ____________.

   d. Ripple timers are asynchronous and use two flip-flops that can count from 0 through ____________.

   e. The first flip-flop in a ripple counter will change state on the ____________ edge of each clock pulse; the second flip-flop will change every time the first flip-flop changes from ____________ to ____________.

   f. In a ripple counter, ____________ gates are used as decoders.

   g. The highest count for a ripple counter is ____________ equal to ____________; ____________ and ____________ gates are used to rest the counter

   h. ____________ counters avoid the delay difficulties of asynchronous counters.

TEST

i. J-K synchronous counters are steered to toggle on receipt of a clock pulse if both J and K inputs are ____________.

j. BCD counters reset to zero after counting to ____________.

k. The ____________ of the BCD counter can be used to supply every tenth clock pulse to the clock line of the next counter.

l. In a D flip-flop counter the ____________ output of the preceding flip-flop is connected to the ____________ input, and the change occurs on the ____________ edge of each clock pulse.

m. A down counter uses ____________ type of flip-flops and uses ____________ for input; the input is preset and causes the counter to count down to ____________.

5. Identify types of display devices according to their characteristics. Read the descriptions below and write the type of digital display being described.

LCD segments	**LED segments**
Electro-mechanical devices	**Dot matrix**
CRT screen	

a. ____

1. React slower because of gears and mechanisms
2. Usually employ solenoids
3. May be noisy
4. Eventually wear mechanically and may fail
5. Require higher current to operate but no current to maintain a constant reading

b. ____

1. Visible in dark
2. Require less power than readout tubes
3. Require more power than LCD segments

TEST

c. ____

1. Not visible in dark without source of light
2. Require less power than LED segments
3. Black segments against light background.

d. ____

1. Can display alphabetical and other characters in addition to numbers
2. May be fiber-optic LED or LCD dots

e. ____

1. Can be shown in conjunction with graphic or wave form display
2. Character shapes, types, and size are virtually unlimited
3. Display requires computer software

6. Distinguish among types of segmented readouts according to their characteristics. Write and "I" beside characteristics that are true of incandescent readouts, and "F" for fluorescent lamp, and "N" for neon or gas tubes, and "L" for light emitting diode characteristics.

_____a. Ten separate cathodes are bent to form the figures 0 through 9

_____b. Uses thin metal element

_____c. Inexpensive and require low voltages to operate (5 VDC typical)

_____d. Similar to a vacuum tube diode

_____e. Seven segments can be either common cathode or common anode

_____f. Bent cathodes glow when conducting electricity

_____g. Plate or anode coated with phosphor that glows when bombarded by the electrons that are attracted to it

_____h. Cold cathode diode gas tubes conduct electricity at a high voltage (usually 50 to 100 volts)

_____i. Seven separate filament wires are used to supply seven segmented readout

_____j. A negative potential applied to the control grid turns off all segments

_____k. A semiconductor diode that produces light emission in its forward bias state

_____l. Also used to form seven-segmented readouts by constructing it with a single anode and seven separate cathodes to form the seven segments A through G

TEST

7. List the parts of an industrial metering circuit and at least one function or characteristic of each part

	PART	FUNCTION
a.	____________________	____________________ ____________________
b.	____________________	____________________ ____________________
c.	____________________	____________________ ____________________
d.	____________________	____________________ ____________________
e.	____________________	____________________ ____________________
f.	____________________	____________________ ____________________

(NOTE: Questions 8 and 9 are the assignment and job sheets they are an important part of this test. If they have not been completed, check with your instructor.)

8. Analyze logic diagrams.

9. Demonstrate the ability to

   a. Construct and analyze a counting and decoding circuit.

   b. Construct and analyze a binary counter.

DIGITAL COUNTING AND METERING CIRCUITS
UNIT IV

ANSWERS TO TEST

1.
   a. 5
   b. 8
   c. 2
   d. 9
   e. 4
   f. 13
   g. 12
   h. 11
   i. 1
   j. 6
   k. 3
   l. 10
   m. 7

2.
   a. Digital to analog
   b. Analog to digital
   c. Flip-flop
   d. Least significant bit
   e. Most significant bit
   f. Binary-coded decimal
   g. Hexadecimal
   h. Liquid crystal display
   i. Binary zero or low
   j. Binary one or high
   k. Used to represent any whole number
   l. Clear or reset
   m. Clock
   n. Set
   o. Reset
   p. The two output labels for a given flip-flop

3.
   a. Set/Reset flip-flop
   b. J-K flip-flop
   c. D flip-flop
   d. And gate
   e. NAND gate
   f. OR gate
   g. NOR gate
   h. Lamp driver

4.
   a. pulses, time, events
   b. R/S, J-K, D
   c. outputs
   d. 3
   e. trailing, 1, 0
   f. AND
   g. 2^{N-1}, OR, NOR
   h. synchronous
   i. high
   j. nine
   k. output
   l. Q, D, leading
   m. D, Q, 0

5.
   a. Electromechanical devices
   b. LED segments
   c. LCD segments
   d. Dot matrix
   e. CRT screen

ANSWERS TO TEST

6\.

a.	N	h.	N
b.	I	i.	I
c.	L	j.	F
d.	F	k.	L
e.	L	l.	N
f.	N		
g.	F		

7. (Answer must list each part and at least one of the following functions or characteristics.)

A. Input buffer amplifier
   1. Isolates circuitry from voltage variations, current loops, surges, etc.
   2. May contain wave-shaping circuitry to square-up distorted waves
   3. May contain filtering to remove high-frequency transients
   4. Provides voltage output compatible to counter input requirements
   5. Input may be a signal from a field mounted transducer or generator

B. Controls
   1. Allows for reset, start/stop, and other basic functions
   2. May control buffer amp to provide sensitivity adjustment to discriminate against low-level noise
   3. May contain circuitry to select counting pulses per unit of time and reset or accumulate counts
   4. May allow for retaining the highest count during a period of time

C. Counter
   1. May be any of the various types of counter circuits
   2. May contain provisions for "programming" by DIP switches, PROMS, etc. to divide the input counts to give corrected rates, to calibrate or compensate for transducer variance, etc.
   3. Output may be in binary code or single pulse for each unit.
   4. Comprised of flip-flops primarily

D. Decoder
   1. Puts output into usable form by converting binary to decimal, BCD, etc.
   2. May automatically reset the counter for a certain end count
   3. Comprised primarily of gates

E. Driver amplifiers
   1. Supplies power to the display
   2. Converts from low level logic to levels required by the display
   3. Comprised of IC operational amplifiers or discrete transistor amplifiers

F. Display
   1. May be electronic or electromechanical
   2. Shows readout of circuit

8. Evaluated to satisfaction of instructor.

9. Performance skills evaluated to satisfaction of instructor.

ANALOG CONTROL
UNIT V

UNIT OBJECTIVE

After completing this unit, the student should be able to identify basic analog control circuitry. The student will show this knowledge by completing assignment sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with analog control to their correct definitions.
2. State meanings of symbols, abbreviations, and acronyms associated with analog controls.
3. Identify control diagrams symbols associated with analog controls.
4. Identify flow diagram symbols associated with analog controls.
5. Match analog circuits to their mathematical functions.
6. Interpret analog control abbreviations.

ANALOG CONTROL
UNIT V

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Provide students with objective sheet.

  B. Provide students with information sheet and assignment sheets.

  C. Make transparencies.

  D. Discuss unit and specific objectives.

  E. Discuss information sheet.

  F. Discuss assignment sheets.

  G. Schedule a field trip to a local industry which employs analog control circuits. Power plants and petro-chemical plants use many types of analog control circuits.

  H. Give test.

  I. Critique test.

  J. Reteach if necessary.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

  D. Transparency masters

    1. TM #1 — Analog Signal Compared to Digital Signal

    2. TM #2 — Differentiation

    3. TM #3 — Integration

    4. TM #4 — Multiplication

    5. TM #5 — Division

    6. TM #6 — Summation

SUGGESTED ACTIVITIES

7. TM #7 — Subtraction

8. TM #8 — Subtraction (Continued)

9. TM #9 — Antalog Functions

E. Assignment sheets

1. Assignment Sheet #1 — Interpret Analog Control Abbreviations

2. Assignment Sheet #2 — Classify Analog Control Systems

F. Answers to assignment sheets

G. Test

H. Answers to test

III. Unit references

A. Lancaster, Don. "Understanding the Op Amp." *Radio-Electronics* magazine, May 1975, pp. 51-58; July 1975, pp. 42-82.

B. *Data Acquisition Components and Subsystems*. Norwood, Massachusetts: Analog Devices, Inc., 1980.

C. *Plant Engineering Directory and Specifications Catalog*, Vol. 16 Leo Spector, ed. Barrington, Illinois: Technical Publishing, Inc., 1981.

ANALOG CONTROL
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Analog — Electronic signal that varies continuously in amplitude

B. Pneumatic — Air or gas operated

C. Hydraulic — Liquid operated

D. Electro-hydraulic — Electrical control of hydraulic system

EXAMPLE: Electro-servo valves controlling hydraulic flow to regulate rate of travel in a hydraulic cylinder lift

E. Dead band — Amount of variation that can take place in the input to an analog control device without affecting the output enough to change a controlling element

EXAMPLE: A pressure switch may open at 50 PSIG when the pressure rises but not close until at 40 PSIG as pressure falls. This represents a 10 PSIG dead band.

F. Range — Operating area between the lowest and highest limits for which a device is designed

EXAMPLE: An analog control-system transmitter may have a range adjusted to from 4 to 20 milliamperes representing a range in pressure which it measures from 0 to 1000 PSIG.

G. Set point — Point at which a device will activate

EXAMPLE: A temperature switch may be set to turn off an oven at 1800°F

H. Trip — Device or action that reacts automatically, usually to allow for safe operation

I. Interlock — One device connected to another to prevent operation of the second device until certain conditions are met with the first device

(NOTE: Interlocks are generally installed for safety reasons and may be connected electrically, mechanically, or otherwise.)

J. Override — Device or action for disabling a control or safety interlock to perform maintenance or to allow manual control

INFORMATION SHEET

K. Swinging control — Oscillating action of defective or incorrect controls which causes parameters to change continually from one extreme to another beyond acceptable limits

EXAMPLE: A flow meter located too far downstream may signal a pump to increase volume which the pump does but before the flow reaches the meter it still does not sense the increase so it signals for more and the pump increases more and more. When the flow reaches the meter the pump senses excessive flow so it signals the pump to slow down, which it does, but before the reduced flow is sensed it continues to slow the pump down until it finally senses an extreme insufficient flow and so on.

L. Span — That portion of range used for a specific operation

EXAMPLE: A controller may have a "span" control which adjusts it to output a range from 1 to 5 volts or 1 to 8 volts, etc. The "range" adjustment would adjust the span, e.g. 4 volt range, from 1 to 5 volts or from 2 to 6 volts, etc.

(NOTE: Many control adjustments interfere or interact with one another requiring several adjustments to each.)

M. Linearity — Ability of device to change output in direct proportion with input within a set range

N. Resetability (repeatability) — Ability of a control device at a certain setting to duplicate previous output at the same setting

O. Damping — Prevention of undesirable oscillation in control systems

P. Feedback — A portion of output that is returned to the controller for control purposes.

(NOTE: Feedback may be negative or positive, or regenerative, degenerative.)

II. Symbols, abbreviations, and acronyms (Assignment Sheet #1)

A. Analog signal modifiers

1. $\int$ — Integral, integrator
2. Σ — Summing circuit, summation
3. × — Multiplier
4. ÷ — Divider

INFORMATION SHEET

5. − — Subtractor
6. + — Simple signal voltage addition
7. $\sqrt{\ }$ — Square root
8. $\frac{dA}{dt}$ — Derivative, differentiator
9. log — Logarithmic

B. Analog measurement parameters

1. V-Voltage
2. A—Amperes
3. T—Temperature
    a. °F — Degrees Fahrenheit
    b. °C — Degrees Celsius
    c. °K — Degrees Kelvin
4. PSIG — Pounds per square inch, gauge
5. PSIA — Pounds per square inch, absolute
6. FCP — Foot candle power
7. UV — Ultraviolet
8. IR — Infrared
9. GPM — Gallons per minute
10. RPM — Revolutions per minute
11. in-Hg — Inches of mercury
12. mm-Hg — Millimeters or mercury
13. in-H_20 — Inches of water
14. CFM — Cubic feet per minute
15. FPM — Feet per minute
16. IPS — Inches per second

INFORMATION SHEET

17. BTUH — British thermal units per hour
18. cal — Calories, calibrate
19. Hz — Hertz
20. PPG — Pulses per gallon
21. PPM — Pulses per minute

C. Analog equipment

1. LVDT — Linear variable differential transformer
2. XMTR — Transmitter
3. RCVR — Receiver
4. DAS — Data acquisition system
5. μ P — Microprocessor
6. TC — Thermocouple
7. CPU — Central processing unit
8. AMP — Amplifier
9. EHC — Electro-hydraulic control
10. RTD — Resistive thermal device
11. FL — Filter
12. FS — Flow switch
13. PS — Pressure switch
14. IRLED — Infrared light-emitting diode
15. LASCR — Light-activated, silicon-controlled rectifier
16. I/F — Interface
17. D/A, DAC, #/∩ — Digital to analog converter
18. A/D, ADC, ∩/# — Analog to digital converter
19. λ/# — Optical to digital converter

INFORMATION SHEET

20. λ / ∩ — Optical to analog converter
21. FT — Flow transmitter
22. PT — Pressure transmitter
23. TS — Temperature switch
24. PMG — Permanent magnet generator (tachometer)
25. SAH — Sample-and-hold circuit
26. HOA — Hand, off, automatic mode selector
27. Op Amp, [O/A] — Operational amplifier
28. Demux — Demultiplexer
29. MBB — Make-before-break switch
30. BBM — Break-before-make switch
31. N.O. — Normally open (switch)
32. N.C. — Normally closed (switch), not connected, no connection, numerical control
33. V/F — Voltage to frequency converter
34. VCO — Voltage controlled oscillator
35. F/V — Frequency to voltage converter
36. CV — Control valve
37. SV — Servo valve, solenoid valve, stop valve
38. FC — Flow control
39. FD — Flame detector
40. FDF — Forced draft fan
41. TT — Temperature transmitter
42. MC — Master controller, motor controller
43. Reg — Regulator
44. LS — Level switch

INFORMATION SHEET

45. LT — Level transmitter

46. FM — Flow meter

D. Analog signal parameters

1. SP — Set point

2. HL — High limit

3. LL — Low limit

4. R — Range

5. DB — Dead band

(NOTE: Decibels is dB.)

6. 4/20 — Four to twenty milliampere signal range

(NOTE: A common industrial analog control and monitoring signal ranges from 4 to 20 mA.)

7. mA — Milliamperes

8. mV — Millivolts

9. ms — Milliseconds

10. Δ — Change in

EXAMPLE: ΔP represents a "change in pressure"

11. S.P. — Static Pressure

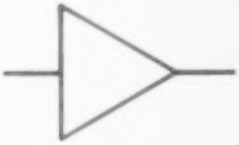
12. V.P. — Velocity Pressure

III. Control diagram symbols (Figures 1-21)

A. Amplifiers

1. Inverting or non-inverting amplifier

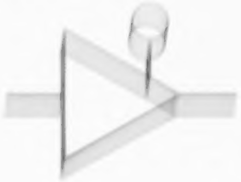
FIGURE 1



INFORMATION SHEET

2. Offset voltage input (bias) amplifier

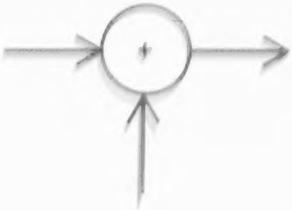
FIGURE 2



B. Summing circuits

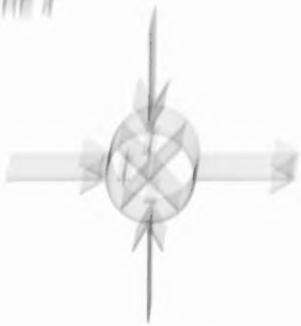
1. Simple combination of values

FIGURE 3



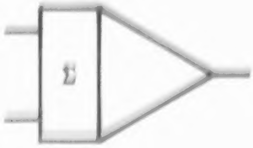
2. Summing and subtracting

FIGURE 4



3. Summing amplifier

FIGURE 5

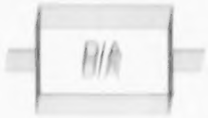


INFORMATION SHEET

C. Converters

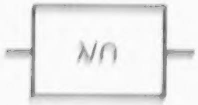
1. Digital to analog

FIGURE 6



2. Optical to analog

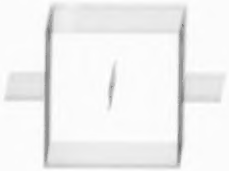
FIGURE 7



(NOTE: Many other combinations of conversion are possible as suggested by the symbols and abbreviations listed in the previous section of this unit.)

D. Integrator

FIGURE 8



2. Integrator amplifier

FIGURE 9

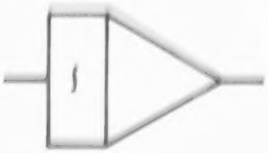
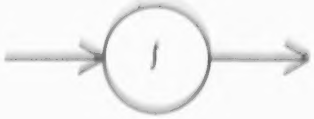


FIGURE 10



INFORMATION SHEET

E. Differentiator

FIGURE 11

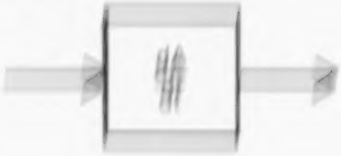
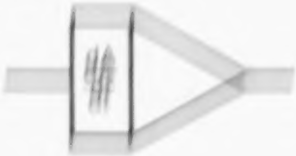


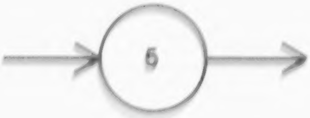
FIGURE 12



F. Multiplier/Divider

1. Multiplier

FIGURE 13



2. Dividers

FIGURE 14

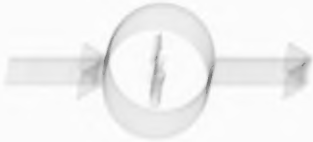
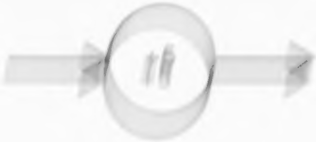
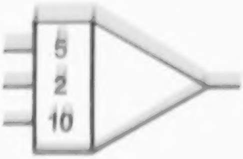


FIGURE 15



3. Combination multiplier and summing amplifier

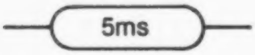
FIGURE 16



INFORMATION SHEET

G. Delay

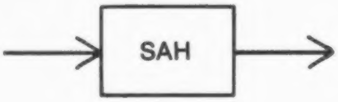
FIGURE 17



H. Other analog devices

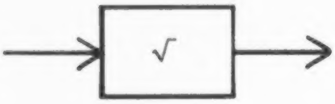
1. Sample-and-hold

FIGURE 18



2. Square root

FIGURE 19



3. Logarithmic

FIGURE 20

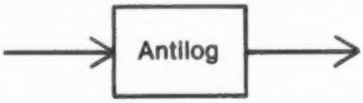
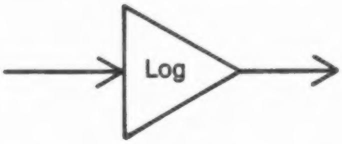


FIGURE 21



(NOTE: Virtually any mathematical operation may be simulated electrically and represented similarly to these. Symbology varies among equipment and manufacturers.)

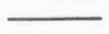
INFORMATION SHEET

IV. Flow diagram symbols (Figures 22-36)

A. Lines and pipes

1. Normal hydraulic or pneumatic line

FIGURE 22



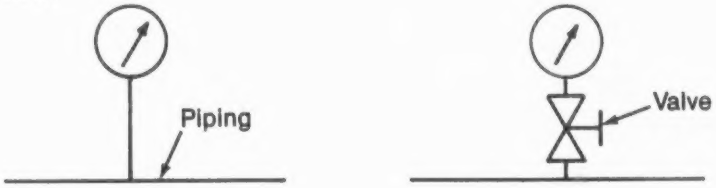
2. Control line

FIGURE 23

B. Gauge or meter

EXAMPLES: Pressure gauge or thermometer

FIGURE 24



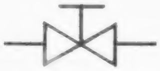
(NOTE: Often a valve is included so that the gauge may be removed for repair or replaced without interrupting flow.)

INFORMATION SHEET

C. Valves

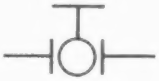
1. Manual gate valve

FIGURE 25



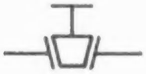
2. Manual ball valve

FIGURE 26



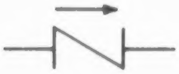
3. Manual gas cock valve

FIGURE 27



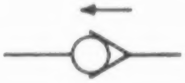
4. Check valve

FIGURE 28



5. Ball check valve

FIGURE 29

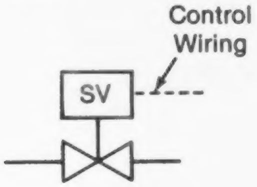


INFORMATION SHEET

6. Solenoid valve

   (NOTE: May also be called "stop valve." This valve is either normally open or normally closed.)

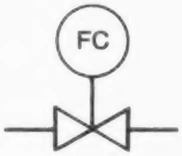
FIGURE 30



7. Automatic flow control valve

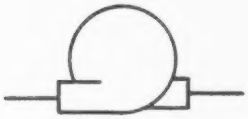
   (NOTE: This valve is adjusted automatically by control devices to regulate flow.)

FIGURE 31



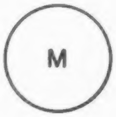
D. Pump

FIGURE 32



E. Motors

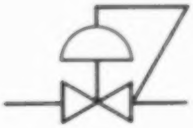
FIGURE 33



INFORMATION SHEET

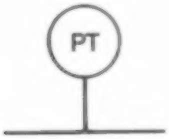
F. Pressure regulator

FIGURE 34



G. Transmitter

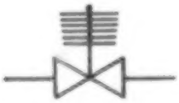
FIGURE 35



H. Pressure relief valve, spring-loaded

(NOTE: Transmitters generally relay information about system temperature, pressure, etc. The symbol usually includes a designation to show the measured parameter.)

FIGURE 36



V. Mathematical functions performed by electronic analog circuitry (Transparencies #2-#8)

A. Differentiation — Function that expresses the change in one variable as related to another

B. Integration — Function that expresses the accumulation of a variable within a range such as time, distance, etc.

C. Multiplication — Linear amplification

D. Division — Linear amplification with gain less than unity or simple voltage divider network

E. Summing — Adding or combining

INFORMATION SHEET

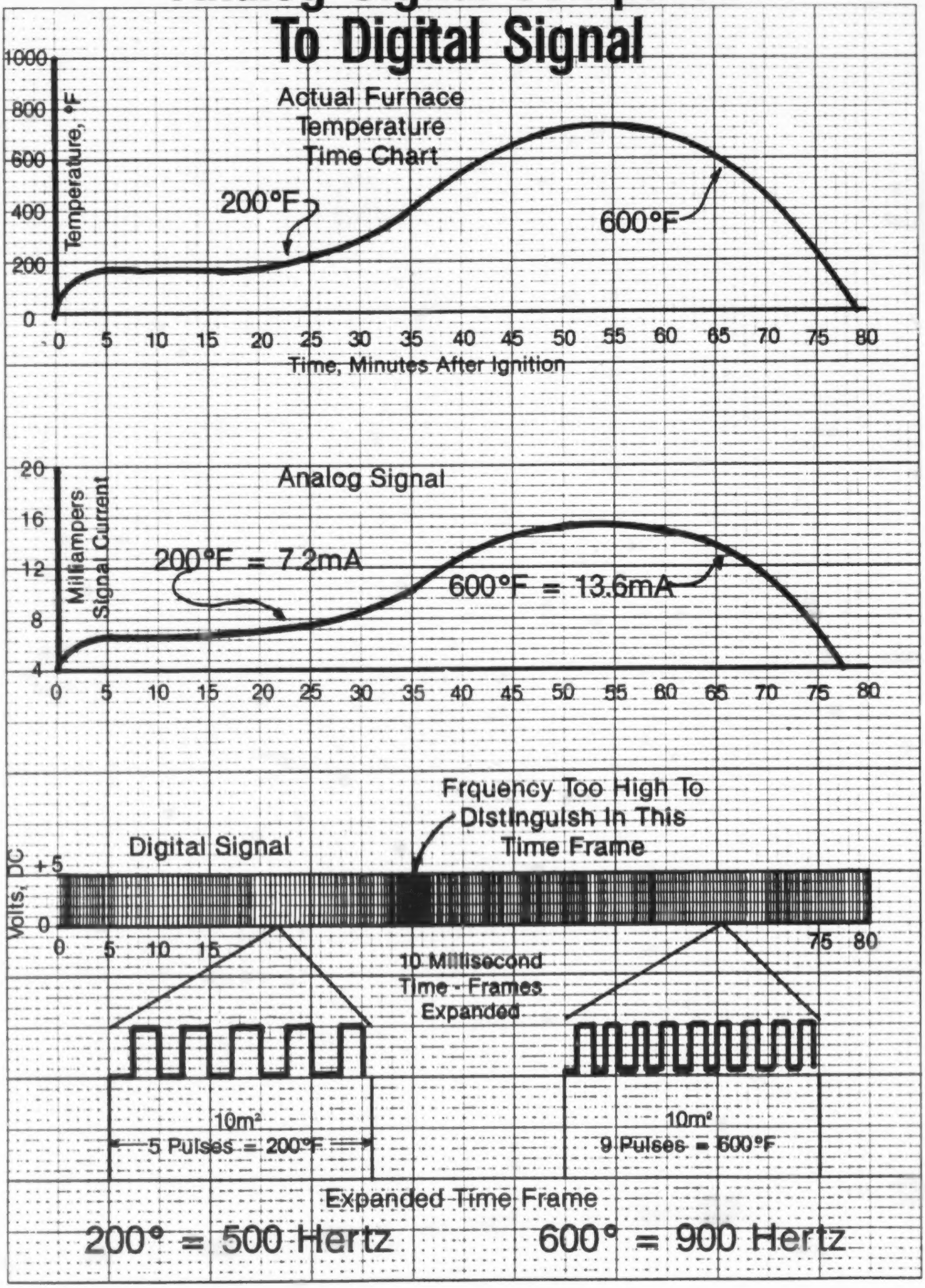
F. Subtraction — Difference or differential amplification

(NOTE: Do not confuse differential with differentiation or differential amplifier with differentiator. A differentiater distinguishes among signals, while a differential amplifier amplifies the difference between two signals.)

G. Log/Analog — Logarithm or antilogarithm functions

(NOTE: There are many circuits that perform other mathematic functions with voltage or curent including square-root, square, RMS, square root of sum of squares, etc.)

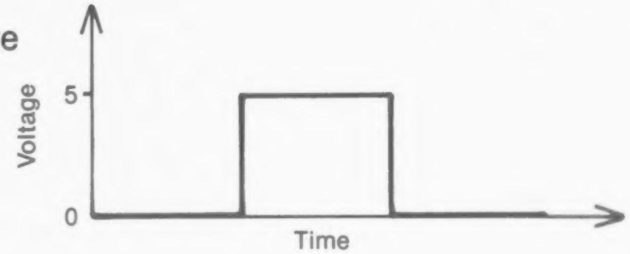
Analog Signal Compared To Digital Signal



Differentiation

Example: Change in voltage as related to time

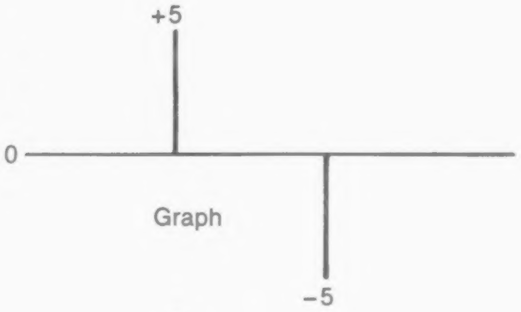
1. Input: Square Wave



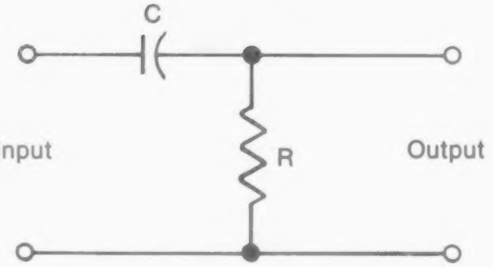
2. Mathematical
Diffential

$$\frac{dV}{dt}$$

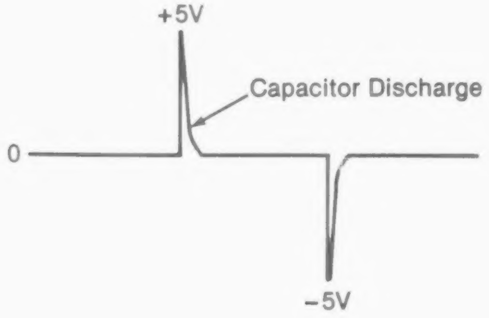
Equation



3. Electronic Differentiator



4. Electronic Output

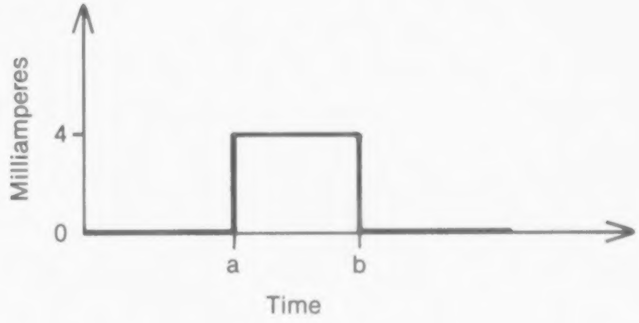


(NOTE: Due to imperfections in components the electronic signal output is not the exact representation of the mathematical plot.)

Integration

Example: Accumulation of current or charge over time span.

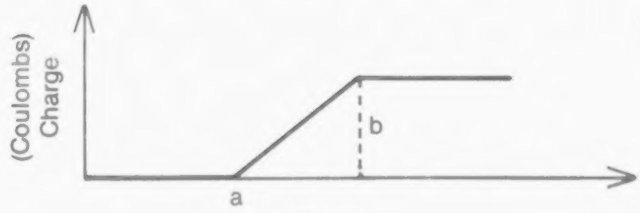
1. Input: Current Flow Square Wave



2. Mathematical Integration

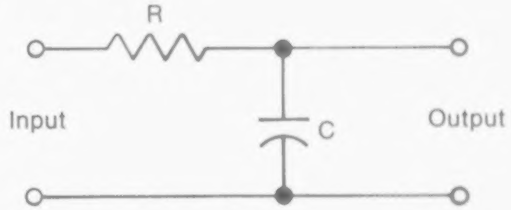
$$\int_a^b f(A)dt$$

Equation

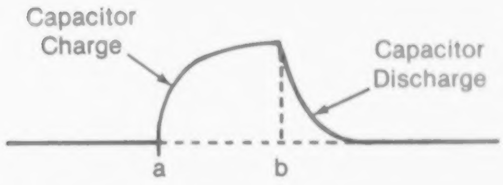


Graph

3. Electronic Integrator



4. Electronic Output

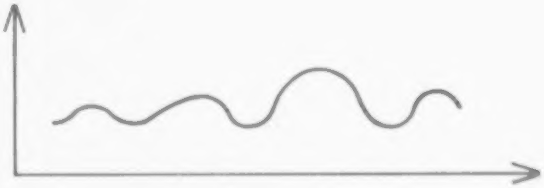


(NOTE: The simple integrator circuit is not capable of holding the accumulated current and is also not linear. Amplification of the linear part of the slope together with a Sample-and-Hold circuit will nearly copy the mathematical graph.)

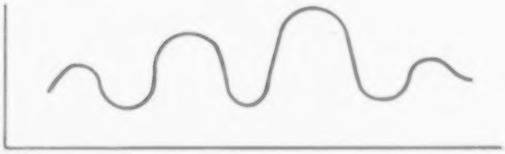
Multiplication

Example: Multiply by factor of 2.

1. Input

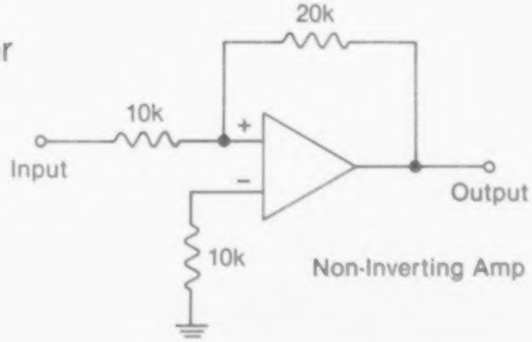


2. Mathematical
Product
A × 2
(Equation)

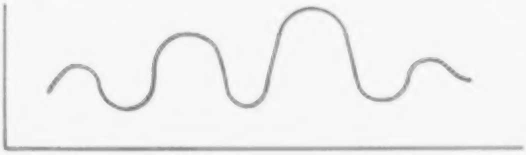


(Graph)

3. Electronic Amplifier


20k
10k
+
−
Input
Output
10k
Non-Inverting Amp

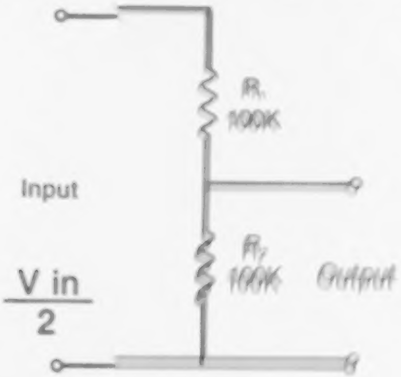
4. Electronic Output
(Twice the Input)



(NOTE: The standard operational amplifier connected in the standard configuration inverts the signal.)

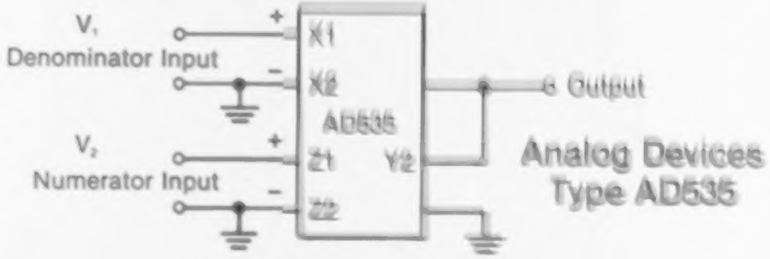
Division

Example: Divide by voltage divider network.


Input
R_1
100K
R_2
100K
Output

Equation: $Vo = \frac{V\ in}{2}$

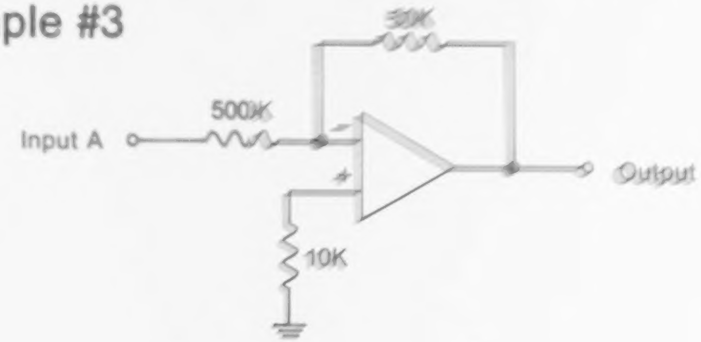
Example #2: Divide one voltage by another.


V_1
Denominator Input
V_2
Numerator Input
+
−
+
−
X1
X2
AD535
Z1
Y2
Z2
Output
Analog Devices
Type AD535

Equation: $Vo = \frac{V_2}{V_1}$

(NOTE: The −10 factor can be elimanated by connecting the output to an inverting amplifier and a dividing network if necessary.)

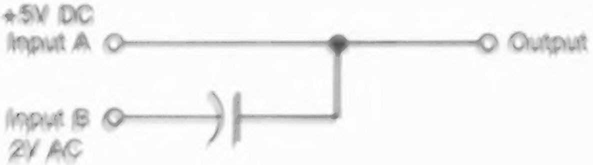
Example #3


50K
500K
Input A
−
+
Output
10K

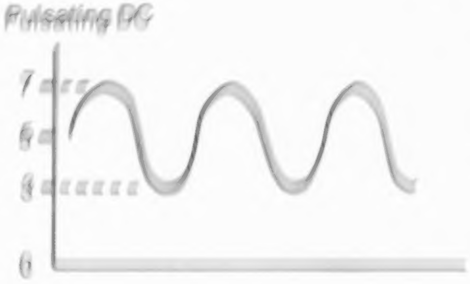
Equattion: $-Vo = \frac{A}{10}$

Summation

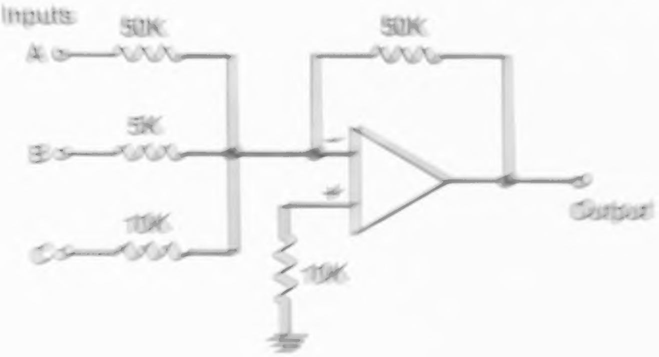
Example #1: Simple Combining of Two Voltages


+5V DC
Input A
Output
Input B
2V AC

Equation: Vo = A+B



Example #2: Summing Amplifier

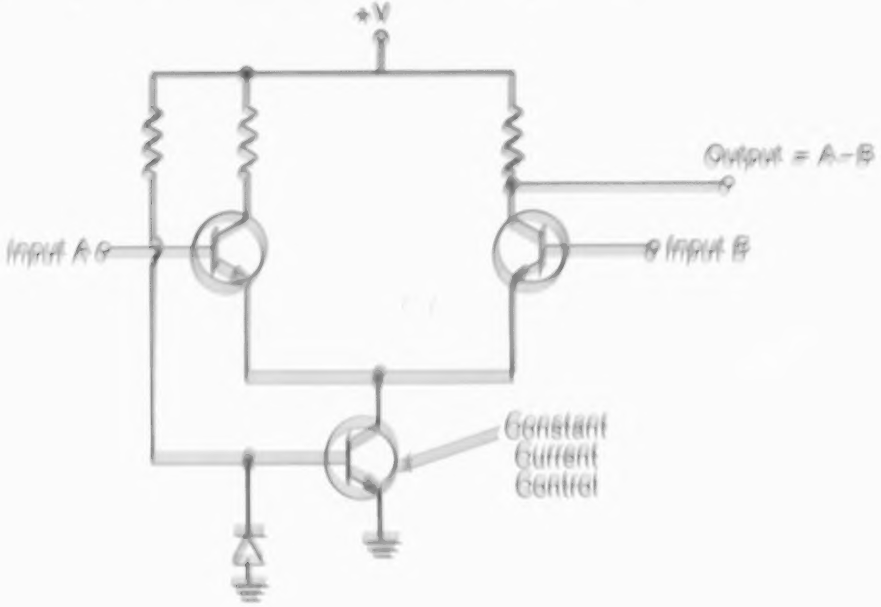

Inputs
50K
A
5K
B
10K
C
50K
−
+
10K
Output

Equation: $-V_o = A + 10B + 5C$

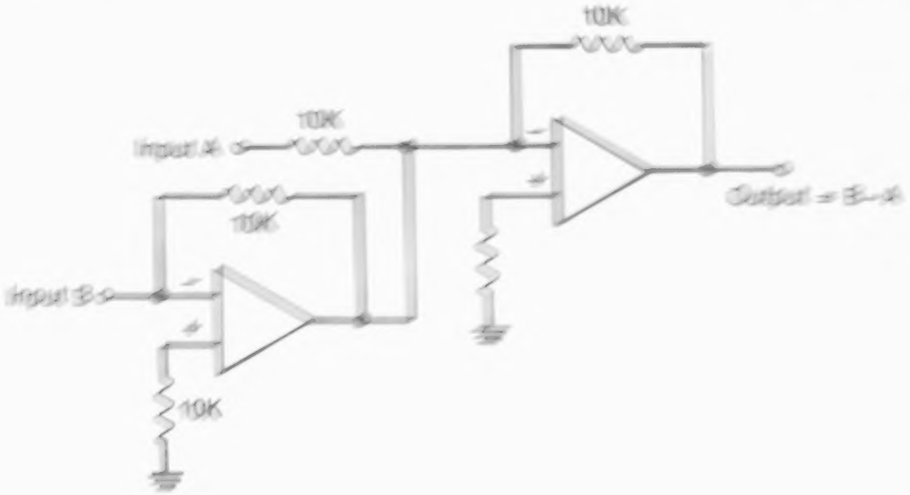
(NOTE: The input resistance divided into the feedback resistor equals that input's amplification factor.)

Subtraction

Example #1: Differential Amplifier


+V
Output = A−B
Input A
Input B
Constant
Current
Control

Example #2: Inverter and Summing Amplifier

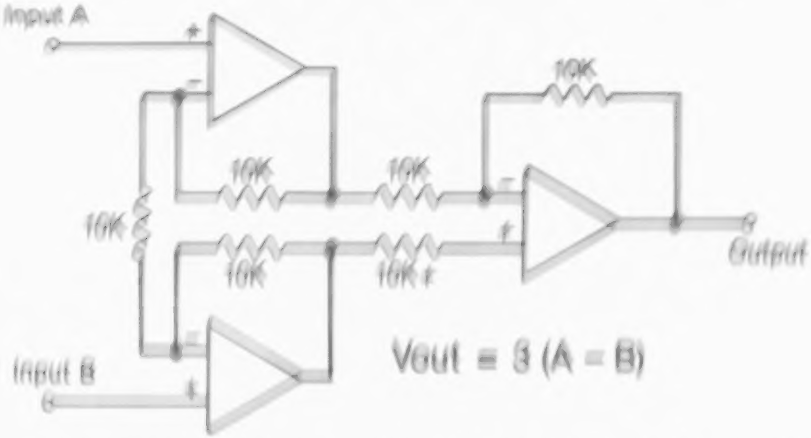

10K
Input A
10K
10K
Input B
10K
Output = B−A

(NOTE: Two inversions make Input B positive in the output equation while A is negative. Hence the output is B−A.)

Subtraction

(Continued)

Example #3: Three-or-Amp Configuration

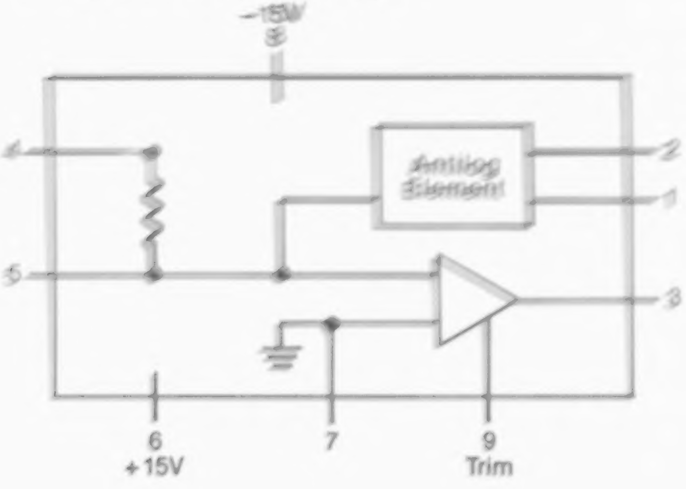

Input A
10K
10K
10K
10K
10K
10K
10K
Output
Input B

$V_{out} = 3\,(A - B)$

(NOTE: Amplification factor depends on the ratio of the resistors.)

Log/Antilog

Example: IC type 755N manufactured by Analog Devices shown below. It is a 9-pin cube-shaped IC package.


−15V
8
4
Antilog Element
2
1
5
3
6
+15V
7
9
Trim

ANALOG CONTROL
UNIT V

ASSIGNMENT SHEET #1 — INTERPRET ANALOG CONTROL ABBREVIATIONS

NAME ______________________________ SCORE ______________

The equipment, schematics, and diagrams of industrial controls will have many abbreviations which technicians must decipher in order to install, maintain, calibrate, or repair the equipment. Without referring to the information sheet, interpret the following abbreviations. Write your answers in the space provided.

1. 30" HGΔP

   ____

2. 20K CFM

   ____

3. UV detector

   ____

4. Δ4mA = 100° C increase

   ____

5. SP = 150 PSIG

   ____

6. 50 GPM = 5 V DC

   ____

7. 20" w.c. s.p.

   ____

8. FM cal: 20 GPM = 40 RPM = 200 PPM = 10 PPG

   ____

ANALOG CONTROL
UNIT V

ASSIGNMENT SHEET #2 — CLASSIFY ANALOG CONTROL SYSTEMS

NAME ______________________________ SCORE ____________

A skilled technician must be able to recognize analog controlled equipment and identify the type of control used, such as pneumatic, hydraulic, or electrical. Tour your school or facility or an industrial plant and list several systems that use analog control. Also describe the type of control being used. Find at least five such systems and turn in to your instructor or discuss in class.

SYSTEM	TYPE OF ANALOG CONTROL
1. ______________________	______________________ ______________________ ______________________
2. ______________________	______________________ ______________________ ______________________
3. ______________________	______________________ ______________________ ______________________
4. ______________________	______________________ ______________________ ______________________
5. ______________________	______________________ ______________________ ______________________

ANALOG CONTROL
UNIT V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. Thirty inches of mercury column difference (or change in) pressure
2. Twenty thousand cubic feet per minute
3. Ultraviolet light detector
4. Change of four milliamperes is equal to one-hundred degrees Celsius increase
5. Set point is equal to one-hundred and fifty pounds pressure per square inch, gauge
6. Fifty gallons per minute equals five volts direct current
7. Twenty inches of water column static pressure
8. Flow meter calibration: twenty gallons per minute equals forty rotations per minute equals two-hundred pulses per minute equals ten pulses per gallon

Assignment Sheet #2 — Evaluated to the satisfaction of the instructor.

ANALOG CONTROL
UNIT V

TEST

NAME ______________________________ SCORE ______________

1. Match the terms on the right to their correct definitions. Write the number of the term in the blank beside its correct definition.

______a. Operating area between the lowest and highest limits for which a device is designed

______b. Liquid operated

______c. Point at which a device will activate

______d. Oscillating action of defective or incorrect controls which causes parameters to change continually from one extreme to another beyond acceptable limits

______e. Electronic signal that varies continuously in amplitude

______f. Device or action that reacts automatically, usually to allow for safe operation

______g. Air or gas operated

______h. Prevention of undesirable oscillation in control systems

______i. Device or action for disabling a control or safety interlock to perform maintenance or to allow manual control

______j. One device connected to another to prevent operation of the second device until certain conditions are met with the first device

______k. A portion of output that is returned to the controller to determine control requirements

______l. Amount of variation that can take place in the input signal to an analog control device without affecting the output enough to change a controlling element

1. Analog 13
2. Pneumatic
3. Hydraulic
4. Electro-hydraulic
5. Dead band
6. Range
7. Set point
8. Trip
9. Interlock
10. Override
11. Swinging control
12. Span
13. Linearity
14. Resetability
15. Damping
16. Feedback

TEST

______m. That portion of range used for a specific operation

______n. Ability of a control device at a certain setting to duplicate previous output at the same setting

______o. Electrical control of hydraulic system

______p. Ability of device to change output in direct proportion with input within a set range

2. State the meanings of symbols, abbreviations, and acronyms associated with analog control. Write the meaning in the space provided.

a. ∫ — ______________________________

b. Σ — ______________________________

c. × — ______________________________

d. ÷ — ______________________________

e. − — ______________________________

f. + — ______________________________

g. √‾ — ______________________________

TEST

h. $\frac{dA}{dt}$ — ____________________

i. log — ____________________

j. V — ____________________

k. A — ____________________

l. T — ____________________

m. °F — ____________________

n. °C — ____________________

o. °K — ____________________

p. PSIG — ____________________

q. PSIA — ____________________

TEST

r. FCP — ______________________________

s. UV — ______________________________

t. IR — ______________________________

u. GPM — ______________________________

v. RPM — ______________________________

w. in-Hg — ______________________________

x. mm-Hg — ______________________________

y. in-H_2O — ______________________________

z. CFM — ______________________________

aa. FPM — ______________________________

TEST

bb. IPS — ____________________

cc. BTUH — ____________________

dd. cal — ____________________

ee. Hz — ____________________

ff. PPG — ____________________

gg. PPM — ____________________

hh. LVDT — ____________________

ii. XMTR — ____________________

jj. RCVR — ____________________

kk. DAS — ____________________

TEST

ll. μP — ____________________

mm. TC — ____________________

nn. CPU — ____________________

oo. AMP — ____________________

pp. EHC — ____________________

qq. RTD — ____________________

rr. FL — ____________________

ss. FS — ____________________

tt. PS — ____________________

uu. IRLED — ____________________

vv. LASCR — ____________________

TEST

ww. I/F — ______________________________

xx. D/A, DAC, #/∩ — ______________________________

yy. A/D, ADC, ∩/# — ______________ ______________

zz. λ/# — ______________________________

aaa. λ/∩ — ______________________________

bbb. FT — ______________________________

ccc. PT — ______________________________

ddd. TS — ______________________________

eee. PMG — ______________________________

fff. SAH — ______________________________

TEST

ggg. HOA — ______________________________

hhh. Op Amp, O/A — ______________________________

iii. Demux — ______________________________

jjj. MBB — ______________________________

kkk. BBM — ______________________________

lll. N.O. — ______________________________

mmm. N.C. — ______________________________

nnn. V/F — ______________________________

ooo. VCO — ______________________________

ppp. F/V — ______________________________

TEST

qqq. CV — ____________________

rrr. SV — ____________________

sss. FC — ____________________

ttt. FD — ____________________

uuu. FDF — ____________________

vvv. TT — ____________________

www. MC — ____________________

xxx. Reg — ____________________

yyy. LS — ____________________

zzz. LT — ____________________

TEST

aaaa. FM — ______________________________

bbbb. SP — ______________________________

cccc. HL — ______________________________

dddd. LL — ______________________________

eeee. R — ______________________________

ffff. DB — ______________________________

gggg. 4/20 — ______________________________

hhhh. mA — ______________________________

iiii. mV — ______________________________

jjjj. ms — ______________________________

TEST

kkkk. Δ —

llll. S.P. —

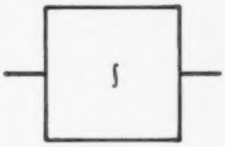
mmmm. V.P. —

3. Identify control diagram symbols. Write the correct name under each illustration.

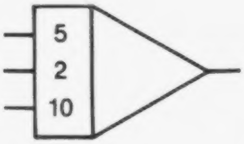
Inverting or noninverting amplifier
Offset voltage input (bias) amplifier
Simple combination of values summing circuits
Summing and subtracting
Summing amplifier
Digital to analog converter
Optical to analog converter

Integrator
Integrator amplifier
Differentiator
Multiplier
Divider
Combination multiplier and summing amplifier
Delay

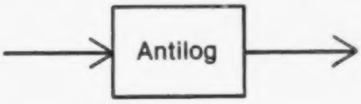
Sample-and-hold device
Square root device
Logarithmic device



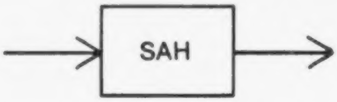
a.



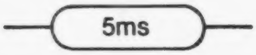
b.



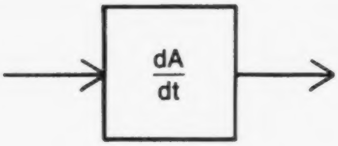
c.



d.

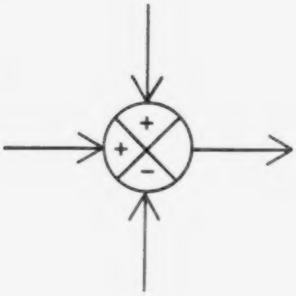


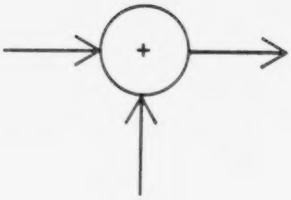
e.



f.

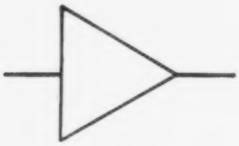
TEST

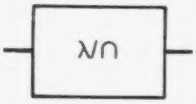




g. ____________________

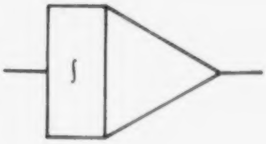
h. ____________________

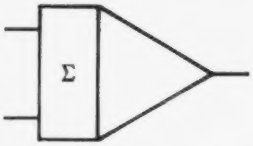




i. ____________________

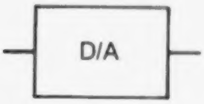
j. ____________________

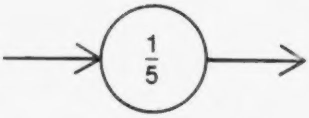




k. ____________________

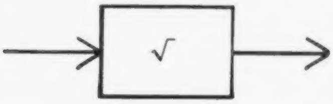
l. ____________________

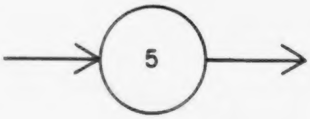




m. ____________________

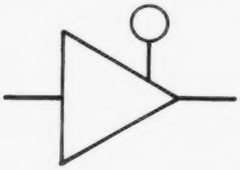
n. ____________________





o. ____________________

p. ____________________



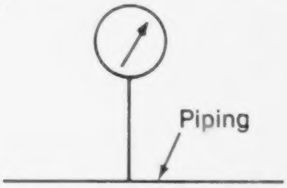
q. ____________________

TEST

4. Identify flow diagram symbols. Write the correct name under each symbol illustrated below.

Normal hydraulic or pneumatic line
Control line
Gauge or meter
Manual gate valve
Manual ball valve
Manual gas cock valve
Check valve
Transmitter

Ball check valve
Solenoid valve
Automatic flow control valve
Pump
Motor
Pressure regulator
Pressure regulator
Pressure relief valve, spring-loaded



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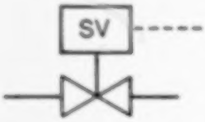

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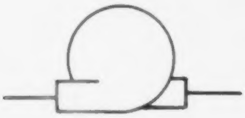

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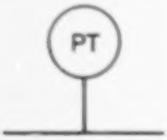

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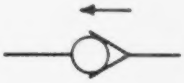

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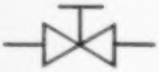

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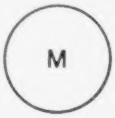

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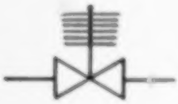

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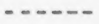

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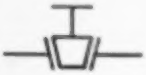
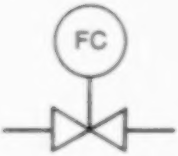
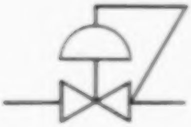


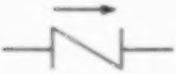
j. ______________________

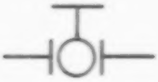
TEST



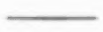


k. ______________________________ l. ______________________________





m. ______________________________ n. ______________________________



0. ______________________________

5. Match analog circuits to their correct mathematical functions. Write the number of the circuit beside its correct function.

_____a. Function that expresses the change in one variable as related to another	1. Division
	2. Multiplication
_____b. Function that expresses the accumulation of a variable within a range such as time, distance, etc.	3. Summing
	4. Integration
_____c. Linear amplication	5. Subtraction
_____d. Linear amplification with gain less than unity or simple voltage divider network	6. Differentiation
_____e. Adding or combining	7. Log/Analog
_____f. Difference or differential amplification	
_____g. Logarithm or antilogarithm functions	

6. Interpret analog control abbreviations.

(NOTE: Test item 6 is an assignment sheet. If you have not completed it, check with your instructor.)

ANALOG CONTROL
UNIT V

ANSWERS TO TEST

1. a. 6
b. 3
c. 7
d. 11
e. 1
f. 8
g. 2
h. 15
i. 10
j. 9
k. 16
l. 5
m. 12
n. 14
o. 4
p. 13

2.

a.	Integral, integrator	b.	Summary circut, summation
c.	Multiplier	d.	Divider
e.	Subtractor	f.	Simple signal voltage addition
g.	Square root	h.	Derivative, differentiator
i.	Logarithmic	j.	Voltage
k.	Amperes	l.	Temperature
m.	Degrees Farenheit	n.	Degrees Celsius
o.	Degrees Kelvin	p.	Pounds per square inch, gauge
q.	Pounds per square inch, absolute	r.	Foot candle power
s.	Ultraviolet	t.	Infrared
u.	Gallons per minute	v.	Revolutions per minute
w.	Inches of mercury	x.	Millimeters of mercury
y.	Inches of water	z.	Cubic feet per minute
aa.	Feet per minute	bb.	Inches per second
cc.	British Thermal Units per hour	dd.	Calories, calibrate
ee.	Hertz	ff.	Pulses per gallon
gg.	Pulse per minute	hh.	Linear variable differential transformer
hh.	Linear variable differential transformer	ii.	Transmitter
jj.	Receiver	kk.	Data requisition system
kk.	Data requisition system	ll.	Microprocessor
mm.	Central processing unit	nn.	Central processing unit
oo.	Amplifier	pp.	Electro-hydraulic control
qq.	Resistive thermal device	rr.	Filter
rr.	Filter	ss.	Flow switch
tt.	Pressure switch	uu.	Infrared light-emitting diode
vv.	Light-activated, silicon-controlled rectifier	ww.	Interface
xx.	Digital to analog converter	yy.	Analog to digital converter
zz.	Optical to digital converter	aaa.	Optical to analog converter
bbb.	Flow transmitter	ccc.	Pressure transmitter
ddd.	Temperature switch	eee.	Permanent magnet generator (tachometer)
eee.	Permanent magnet generator (tachometer)	fff.	Sample-and-hold circuit
ggg.	Hand, off, automatic mode selector	hhh.	Operational amplifier
iii.	Demultiplexer	jjj.	Make-before-break switch
kkk.	Break-before-make switch	lll.	Normally open
mmm.	Normally closed, not connected	nnn.	Optical to analog converter
ooo.	Voltage controlled oscillator	ppp.	Frequency to voltage converter
qqq.	Control valve	rrr.	Servo valve, solenoid valve
sss.	Flow chart	ttt.	Flame detector

ANSWERS TO TEST

uuu. Forced draft fan
vvv. Temperature transmitter
www. Master controller, motor controller
xxx. Regulator
yyy. Level switch
zzz. Level transmitter
aaaa. Flow meter
bbbb. Set point
cccc. High limit
dddd. Low limit
eeee. Range
ffff. Dead band
gggg. Four to twenty milliampere range
hhhh. Milliamperes
iiii. Millivolts
jjjj. Milliseconds
kkkk. Change in
llll. Static pressure
mmmm. Velocity pressure

3. a. Integrator
b. Combination multiplier and summary ampli
c. Logarithmic device
d. Sample-and-hold device
e. Delay
f. Differentiator
g. Summing and subtracting circuit
h. Simple combination of values circuit
i. Inverting or noninverting amplifier
j. Optical to analog converter
k. Integrator amplifier
l. Summing amplifier
m. Digital to analog converter
n. Divider
o. Square root device
p. Multiplier
q. Offset voltage input (bias) amplifier

4. a. Gauge or meter
b. Solenoid valve
c. Pump
d. Transmitter
e. Ball check valve
f. Manual gate valve
g. Motor
h. Pressure relief valve, spring-loaded
i. Control line
j. Manual gas cock valve
k. Automotive flow control valve
l. Pressure regulator
m. Check valve
n. Manual ball valve
o. Normal hydraulic or pneumatic line

5. a. 6
b. 4
c. 2
d. 1
e. 3
f. 5
g. 7

6. Evaluated to the satisfaction of the instructor.

ANALOG CONTROL CIRCUITS
UNIT VI

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and analyze analog control circuits. The student will show this knowledge by completing an assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with analog control circuits to their correct definitions.
2. Select from a list characteristics of analog control circuits.
3. List applications of analog control circuits.
4. Match types of analog control to their correct descriptions.
5. Identify analog amplifier configurations by their symbols and output formulas.
6. Determine the output of a combination multiplier and summing amplifier.
7. Classify types of control systems.
8. Demonstrate the ability to
   a. Construct and analyze passive integrating and differentiating analog circuits.
   b. Construct and analyze an active integrator circuit.
   c. Construct and analyze a summing circuit.

ANALOG CONTROL CIRCUITS
UNIT VI

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Review unit and plan presentation.

   B. Obtain materials necessary to supplement presentation.

   C. Provide students with objective sheet.

   D. Introduce unit and discuss objectives; review analog control theory if necessary.

   E. Provide students with information, assignment, and job sheets.

   F. Discuss information and assignment sheets.

   G. Provide class with examples and demonstrations of analog control circuits performing various functions.

   H. Demonstrate each type of control.

   I. Demonstrate and discuss job sheet procedures; review previous material on filtering circuits if necessary to prepare students for Job Sheet #1.

   J. Allow students to complete job sheets.

   K. Give test.

   L. Reteach and retest if necessary.

   M. Complete appropriate sections of competency profiles.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1 — Analog Signal Compared to Digital Signal

      2. TM #2 — Log/Analog Graphs

SUGGESTED ACTIVITIES

3. TM #3 — Chemical Mixture Control

4. TM #4 — Mixed Chemical Heat Reactor

E. Assignment Sheet #1 — Classify Types of Control Systems

F. Answers to assignment sheet

G. Job sheets

1. Job Sheet #1 — Construct and Analyze Passive Integrating and Differentiating Analog Circuits

2. Job Sheet #2 — Construct and Analyze an Active Integrator circuit

3. Job Sheet #3 — Construct and Analyze summing Circuit

H. Unit test

I. Answers to test

III. Unit References

A. Chirlian, Paul M. *Electronics Circuits: Physical Principles Analysis and Design.* New York: McGraw-Hill Book Company, 1971.

B. Shrader, Robert L. *Electronic Communication.* New York: McGraw-Hill Book Company, 1975.

ANALOG CONTROL CIRCUITS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

  A. Analog control circuit — Wires and devices arranged to control equipment by an analog signal

  B. Hydraulic — Use of a fluid to perform work

  C. Optical — Use of light rays to transmit or signal a control function

  D. Interface — To connect with and make compatible for communications to other equipment

  E. Control circuit — That portion of an electrical circuit which initiates a change in the function of a device

II. Characteristics of analog control circuits

  A. Uses steady analog control signal

  B. Slower reactive time than digital control circuits

  C. Susceptible to induced voltage errors caused by transients

  D. Must have special equipment to interface with computers

III. Applications of analog control circuits

  A. Convert transducer or sensor output into usable voltage or current signal

  EXAMPLE: A pressure transducer may produce a nonlinear output. Analog control devices can convert nonlinear variations to linear variations.

  B. Manipulate measured values representing pressures, flows, temperatures, etc. to mathematically combine them to control complex systems

  EXAMPLE: A chemical processing plant may require the precise mixing of two parts of one chemical with three parts of another. An analog control circuit can be adjusted to monitor the flows and control the pumps in a continuous flow process for the correct mixture.

  C. Ensure safe operation of systems

  EXAMPLE: A chemical reaction furnace may employ controls to ensure proper fuel and air mixture and flame detection. The control system can also ensure that chemicals or processes do not become overheated which could result in hazards to employees, possible equipment damage, and loss of production material.

INFORMATION SHEET

D. Provide signals for monitoring and recording

EXAMPLE: To ensure the safety and quality of a process it may require that many parameters be monitored by meters, gauges, indicators, and recorders.

IV. Types of analog control

(NOTE: Control systems may also be categorized as analog or digital. Analog systems may be categorized as linear or nonlinear. Additionally, control is classed as open-ended or feedback, on/off or variable, and automatic or manual.)

A. Open-ended (open loop) control — System with no feedback loops required

(NOTE: This type of control can be compared to a traffic light system that works only with timers and assumes that traffic will not be lined up waiting in one direction while there is no traffic in the cross direction. The system contrasts to the modern traffic control lights that have traffic sensors which adjust the light switching according to automobiles in the various lanes as well as pedestrian requests to cross.)

B. Feedback (closed loop) control — Monitors the controlled actions and automatically adjusts the control to meet system requirements

(NOTE: Virtually any complex control system has feedback loops to correct for deviations from the desired control. An industrial steam boiler will have temperature and pressure sensors that control the burners to ensure that the correct amount of heat is maintained. The sensors control the gas valves automatically to the present valves.)

C. On/Off control — Control by turning elements on and off as opposed to varying the amount of operation

(NOTE: On/Off control may be open-ended or feedback. An on/off feedback control functions similarly to the ordinary household wall thermostat and heater. When the house is warm enough the heater turns off. When it becomes cool, the heater comes on. An open-ended on/off control can be compared to industrial outdoor lighting on a timer. The lights are turned on or off according to the time of day with no feedback to ensure that the lights are on or that they are only on when it is dark.)

D. Variable control — Controlling elements operate at any degree between off and full power

(NOTE: Variable control may be open-ended or feedback. A variable volume pump may be controlled by a variable speed motor and the control loop may incorporate a turbine flow meter that senses the flow rate to correct the motor speed. The pump may vary from 0 GPM to 100 GPM proportionally to the demand control signal input from a chemical refining system.)

INFORMATION SHEET

E. Automatic control — Control is ordinarily accomplished without operator intervention

(NOTE: In automatic operation, the equipment responds to operating conditions without operator intervention. For example, a chemical refinery may mix chemicals in quantities required by controlled flow rates of supply pipelines according to flow meter signals corrected according to temperature and viscosity. This would be an automatic variable feedback control system.)

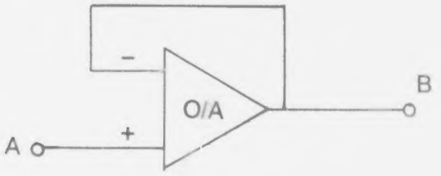
F. Manual control — Requires operator monitoring and manipulation

(NOTE: Manual control requires an operator, a monitoring device, and a control mechanism. For example, a gas line pump station operator may increase pump pressure when necessary by adjusting a bypass valve when the pressure gauge on the line indicates it is below the desired value.)

V. Analog amplifier configurations and output formulas (Figures 1-9)

A. Unity gain, non-inverting (voltage follower)

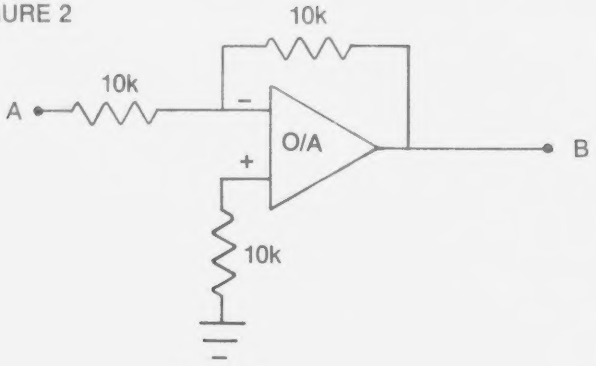
FIGURE 1



B = A

B. Unity gain, inverting

FIGURE 2

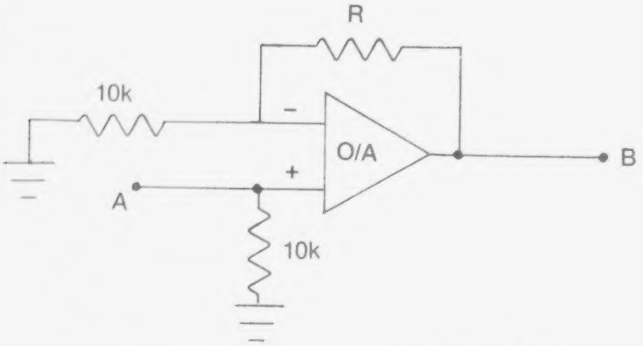


B = –A

INFORMATION SHEET

C. 1+ ratio gain, non-inverting

FIGURE 3



$$B = (1 + \frac{R}{10k})A$$

EXAMPLE: If R is 50K ohms, the output, B, is determined as follows

$$B = (1 + \frac{R}{10K})\ A$$

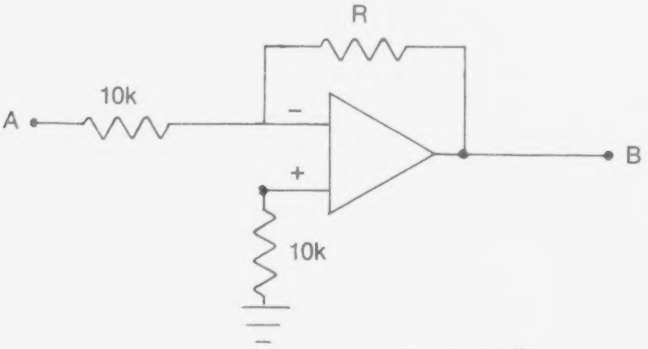
$$B = (1 + \frac{50K}{10K})\ A$$

$$B = (1 + 5)\ A$$

The gain is six.

D. Ratio gain, inverting

FIGURE 4



$$B = (1 - \frac{R}{10k})A$$

INFORMATION SHEET

EXAMPLE: If R = 50K ohms, the output, B, is determined as follows

$$B = \left(\frac{R}{-10K}\right) A$$

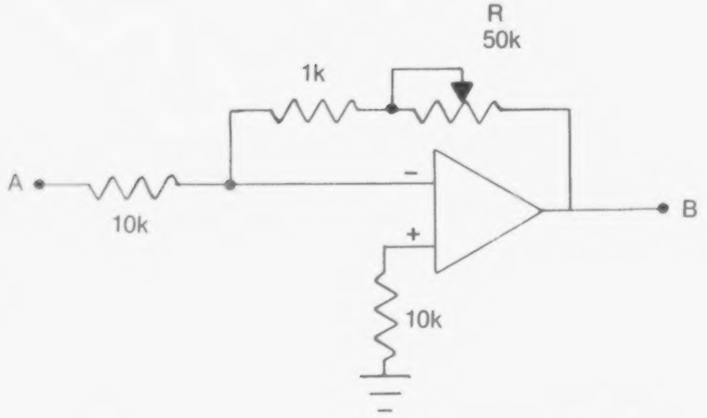
$$B = \left(\frac{50K}{-10K}\right) A$$

$$B = -5A$$

The gain is negative five.

E. Variable gain, inverting

FIGURE 5

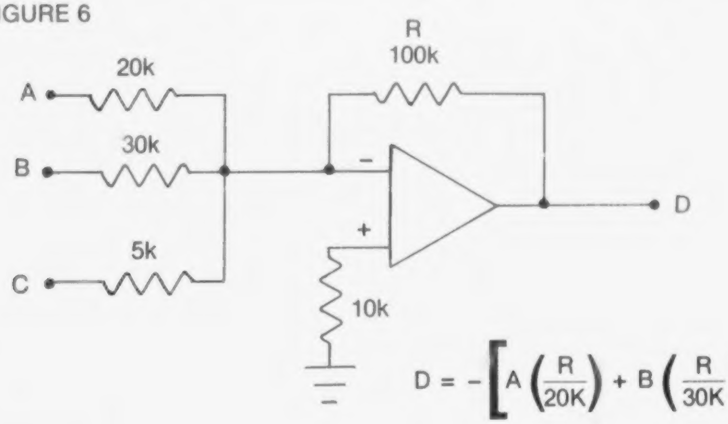


$$B = \left(-\frac{1k + R}{10k}\right)A$$

EXAMPLE: For the circuit shown above, the gain will vary from −.1 to −5.1.

F. Combination, multipliers and summing

FIGURE 6



$$D = -\left[A\left(\frac{R}{20K}\right) + B\left(\frac{R}{30K}\right) + C\left(\frac{R}{5K}\right)\right]$$

INFORMATION SHEET

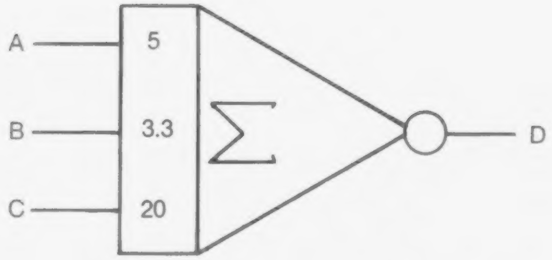
EXAMPLE: For the circuit shown having a 100 Kohm feedback resistor the output, D, is determined as follows

$$D = -[A \frac{100K}{20K} + B (\frac{100K}{30K}) + C (\frac{100K}{5K})]$$

$$D = -(5A + 3.3B + 20C)$$

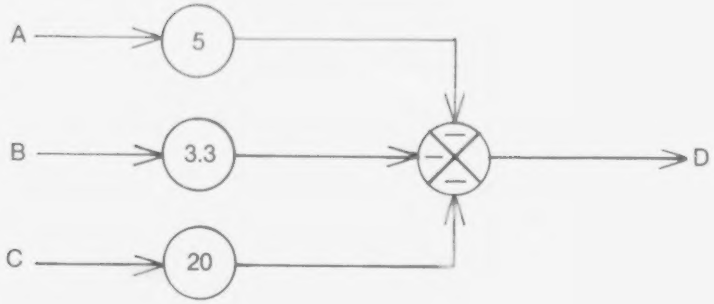
The analog control diagram symbol would be as shown below

FIGURE 7



The same circuit could also be diagrammed as shown below

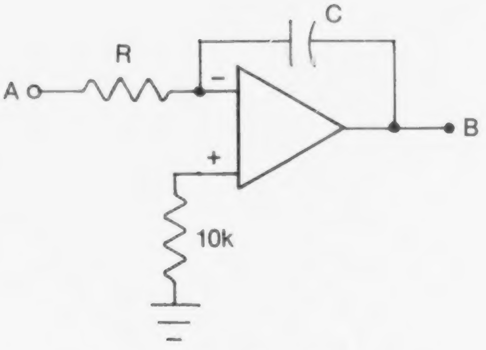
FIGURE 8



INFORMATION SHEET

G. Integrator

FIGURE 9



B = f(t,A,R,C)

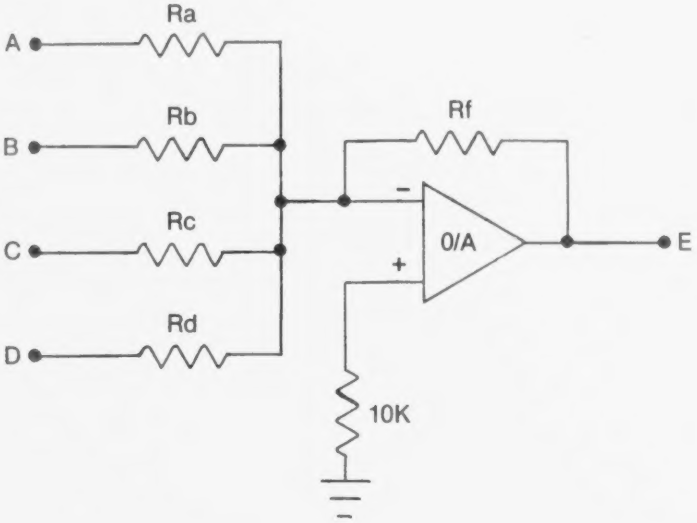
(NOTE: The equation above states that the output is a function of time, the input, R, and C. In other words, the capacitor charge rate will determine the output at any given time.)

VI. Determine the output of a combination multiplier and summing amplifier (Figure 10)

A. For the configuration shown below use the formula:

$$E = -[A\frac{Rf}{Ra} + B\frac{Rf}{Rb} + C\frac{Rf}{Rc} + D\frac{Rf}{Rd}]$$

FIGURE 10



INFORMATION SHEET

B. Enter the resistor values into the formula

EXAMPLE: Suppose Rf is 60K, Ra = 10K, Rb = 20K, Rc = 15K, and Rd = 5K. The formula would appear as below

$$E = -[A \frac{60K}{10K} + B \frac{60K}{20K} + D \frac{60K}{5K}]$$

C. Simplify the equation

EXAMPLE: The equation shown above reduces to the following

$$E = -[6A + 3B + 4C + 12D]$$

D. Enter the input voltage values

EXAMPLE: Suppose A = .5 volts, B = 2 V, C = .3 V, and D = .4 volts. The equation would appear as below.

$$E = -[(6 \times .5) + (3 \times 2) + (4 \times .3) + (12 \times .4)]$$

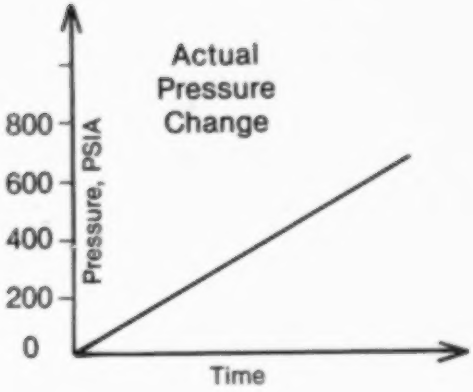
E. Solve the equation for the output

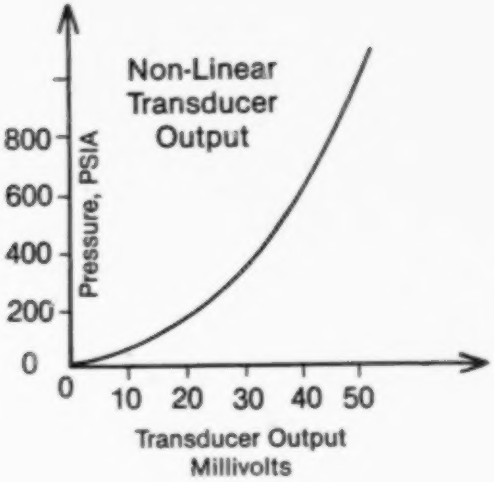
EXAMPLE: The solution to the above equation is shown below

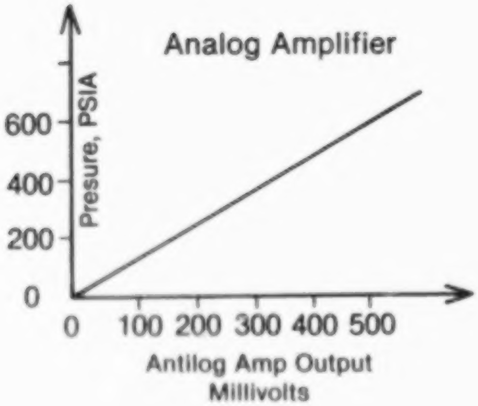
$$E = -[3 + 6 + 1.2 + 4.8]$$

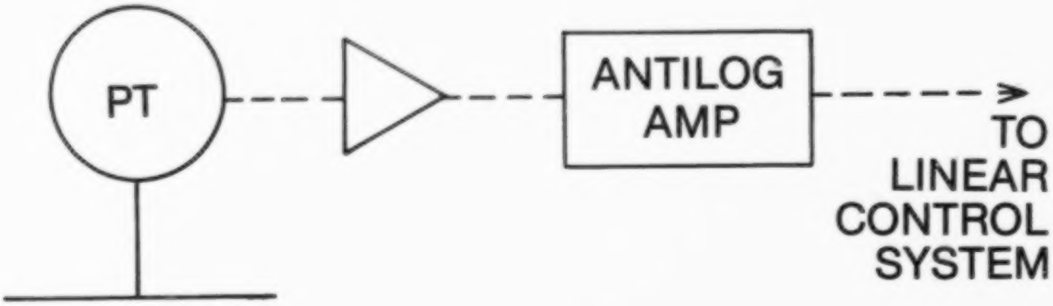
$$E = -15 \text{ volts}$$

Log/Antilog Graphs

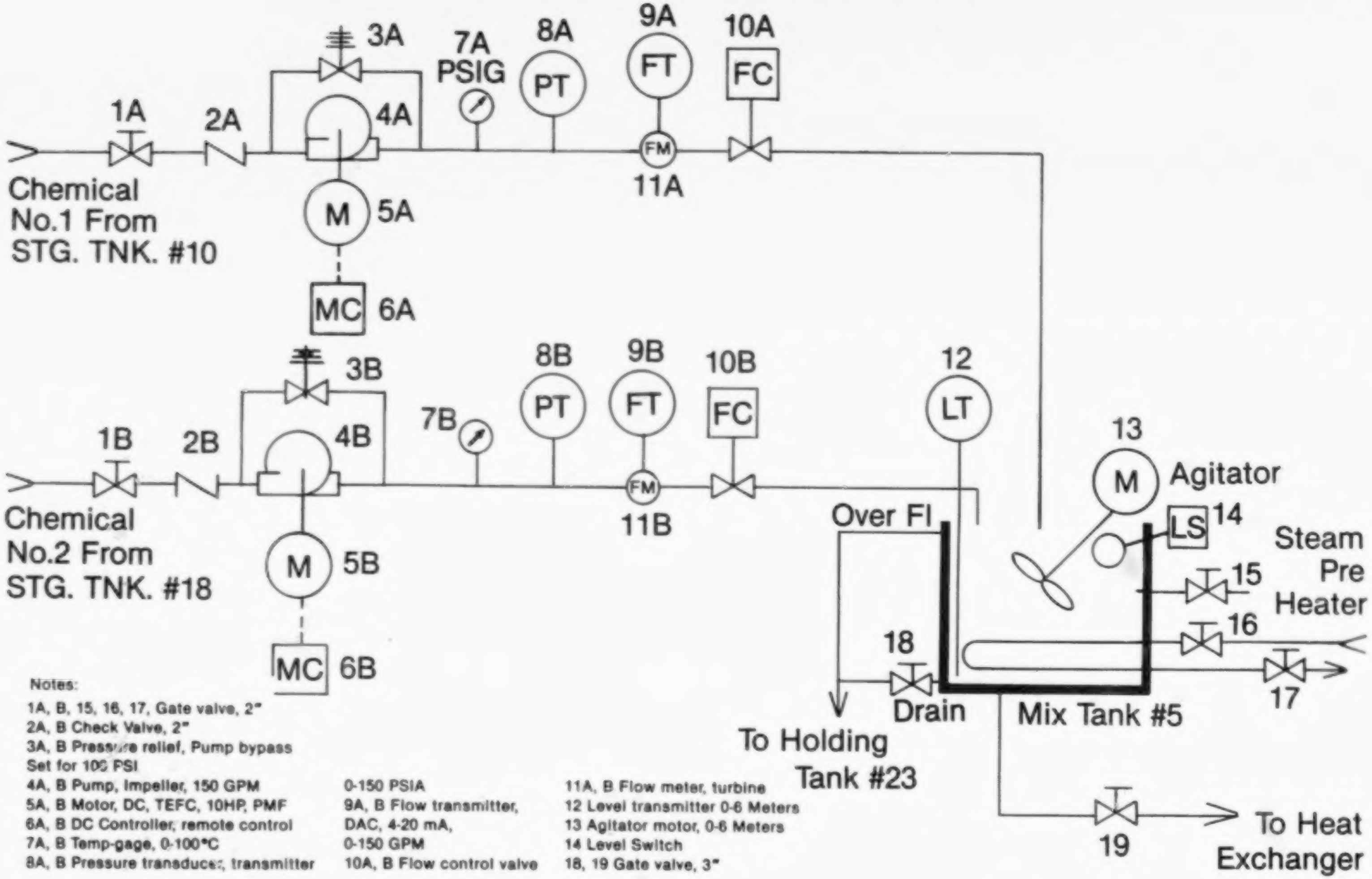







PT
ANTILOG
AMP
TO
LINEAR
CONTROL
SYSTEM

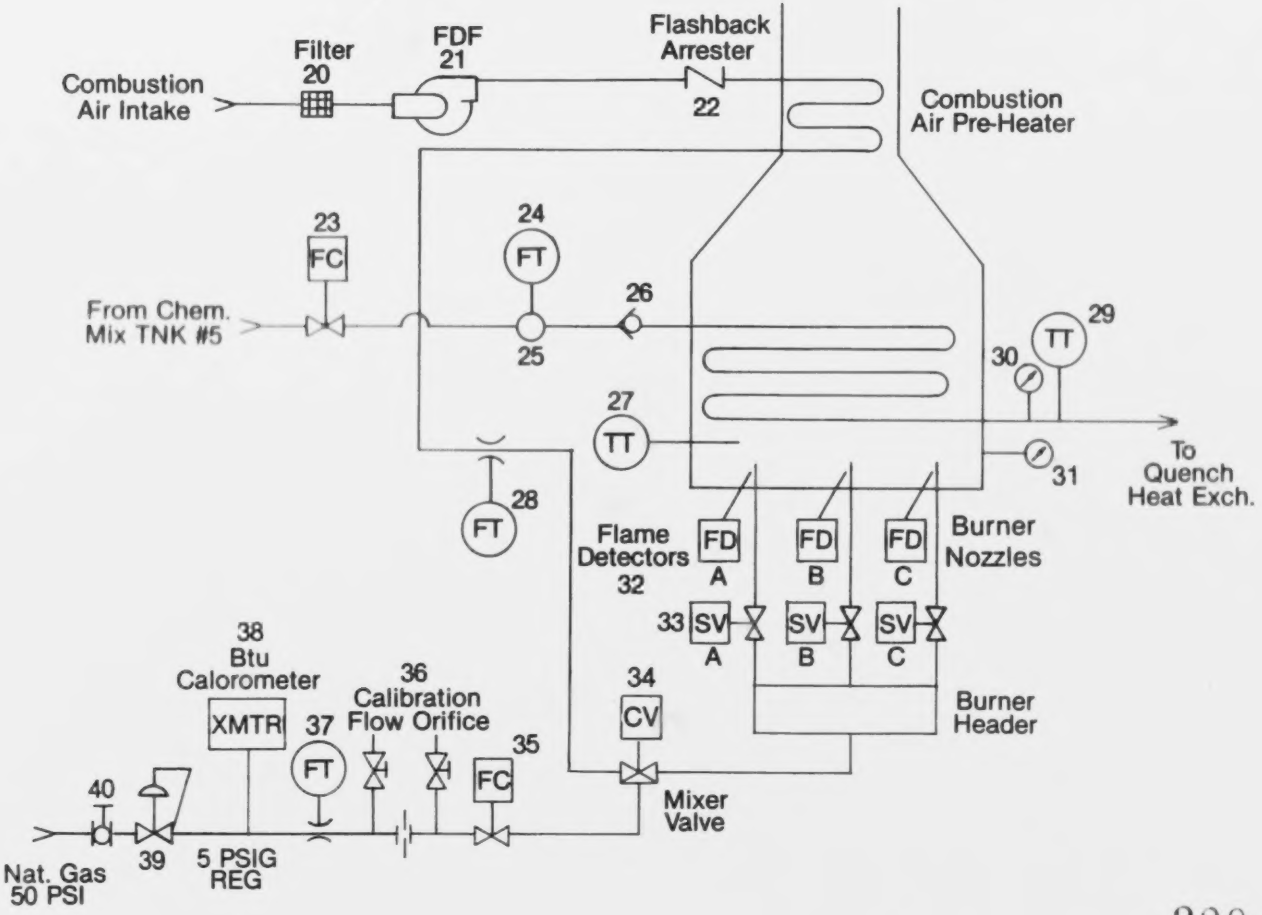
Chemical Mixture Control


1A
2A
3A
4A
5A
6A
MC
M
7A
PSIG
8A
PT
9A
FT
10A
FC
FM
11A
Chemical No.1 From STG. TNK. #10
1B
2B
3B
4B
5B
6B
MC
M
7B
8B
PT
9B
FT
10B
FC
FM
11B
12
LT
13
M
Agitator
LS
14
Over Fl
Steam Pre Heater
15
16
17
18
Drain
Mix Tank #5
To Holding Tank #23
19
To Heat Exchanger
Chemical No.2 From STG. TNK. #18

Notes:

1A, B, 15, 16, 17, Gate valve, 2"
2A, B Check Valve, 2"
3A, B Pressure relief, Pump bypass Set for 100 PSI
4A, B Pump, Impeller, 150 GPM
5A, B Motor, DC, TEFC, 10HP, PMF
6A, B DC Controller, remote control
7A, B Temp-gage, 0-100°C
8A, B Pressure transducer, transmitter 0-150 PSIA
9A, B Flow transmitter, DAC, 4-20 mA, 0-150 GPM
10A, B Flow control valve
11A, B Flow meter, turbine
12 Level transmitter 0-6 Meters
13 Agitator motor, 0-6 Meters
14 Level Switch
18, 19 Gate valve, 3"

Mixed Chemical Heat Reactor


Combustion Air Intake
Filter 20
FDF 21
Flashback Arrester
22
Combustion Air Pre-Heater
23
FC
24
FT
From Chem. Mix TNK #5
26
25
29
TT
30
27
TT
To Quench Heat Exch.
31
FT
28
Flame Detectors 32
FD A
FD B
FD C
Burner Nozzles
33
SV A
SV B
SV C
38 Btu Calorometer
XMTR
36 Calibration Flow Orifice
37
FT
34
CV
Burner Header
35
FC
40
Mixer Valve
Nat. Gas 50 PSI
39
5 PSIG REG

TM #3

PCT - 251-A

ANALOG CONTROL CIRCUITS
UNIT VI

ASSIGNMENT SHEET #1 — CLASSIFY TYPES OF CONTROL SYSTEMS

NAME ______________________________ SCORE ______________

Analog control systems can be classed by the presence or lack of system feedback, the amount of variability in the control, and whether or not an operator is required to intervene.

It is important to recognize the various types in order to effectively work with them.

Classify the examples given below by placing the appropriate letters in the spaces provided to indicate the types of conterol system. In the first blank of each example write "O" for open-ended and "F" for feedback. In the second blank write "O" for on/off and "V" for variable. In the third blank, write "A" for automatic and "M" for manual.

A. An industrial air compressor that turns on and off according to a pressure switch mounted on the air tank.

1. ______________ 2. ______________ 3. ______________

B. An industrial chilled water air-conditioning system controlled by pneumatic valves that open to the amount required to supply the correct flow of chilled water as indicated by the summation of the pneumatic proportional thermostats.

1. ______________ 2. ______________ 3. ______________

C. An oil tank transfer pump turned on and off by an operator to pump from one tank to another.

1. ______________ 2. ______________ 3. ______________

D. An industrial security lighting system turned on and off by a photocell sensor.

1. ______________ 2. ______________ 3. ______________

E. An assembly line that operates with a variable speed drive set by the production foreman each morning.

1. ______________ 2. ______________ 3. ______________

ASSIGNMENT SHEET #1

F. A power factor correction circuit that monitors the KVARS in a plant and connects capacitors through breakers proportionally as required.

1. ____________________ 2. ____________________ 3. ____________________

ANALOG CONTROL CIRCUITS
UNIT VI

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1

A. 1. F
   2. O
   3. A

B. 1. F
   2. V
   3. A

C. 1. O
   2. O
   3. M

D. 1. O
   2. O
   3. A

(NOTE: The photocell is not a feedback device since it does not monitor the controlled parameter [electric lights] but merely monitors the sunlight.)

E. 1. O
   2. V
   3. M

F. 1. F
   2. V
   3. A

ANALOG CONTROL CIRCUITS
UNIT VI

JOB SHEET #1 — CONSTRUCT AND ANALYZE PASSIVE INTEGRATING AND DIFFERENTIATING ANALOG CIRCUITS

I. Tools and materials

A. Laboratory square wave generator, variable frequency from 20 Hz to 2.5 Khertz

B. Oscilloscope, with probe

C. Resistor, 45 Kohms, 1/4 watt

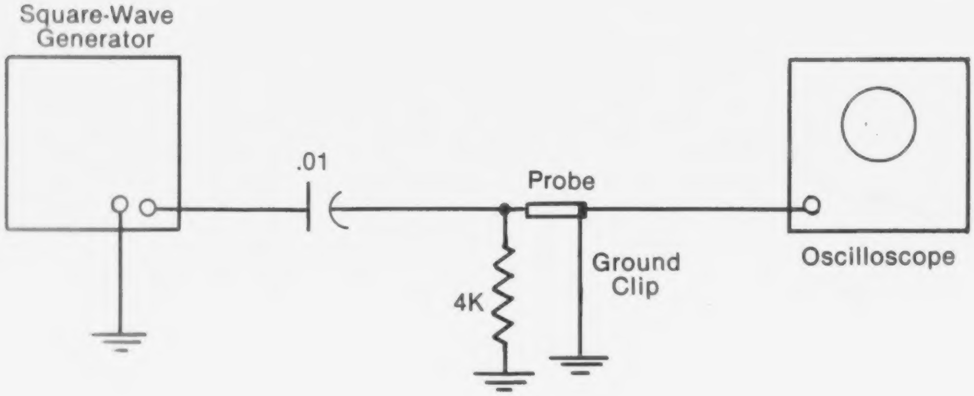
D. Capacitor, .01 μ F, 25 volts

E. Breadboard

II. Procedures

A. Construct the circuit shown below (Figure 11)

FIGURE 11



(NOTE: Have instructor check circuit.)

B. Adjust the square-wave generator for an output of 1 volt peak-to-peak

C. Adjust the oscilloscope for a stable display showing two or three cycles at full-wave amplitude; be certain the probe is adjusted correctly

D. Adjust the generator to 500 hertz

JOB SHEET #1

E. Sketch the output waveform below

F. Set the generator output to 1 Khertz

G. Sketch the output waveform below

H. Adjust the generator output to 1.5 Khertz

I. Sketch the waveform below

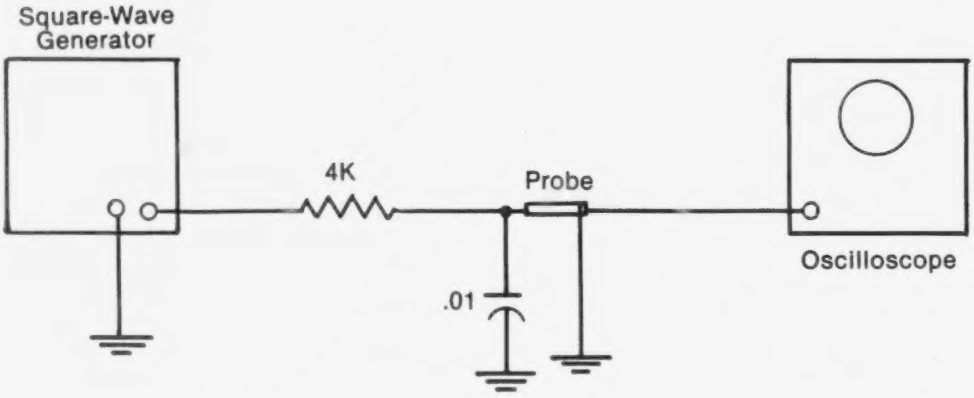
J. Adjust the generator output to 2.0 Khertz

K. Sketch the output waveform below

JOB SHEET #1

L. Rearrange the circuit as shown below (Figure 12)

FIGURE 12


Square-Wave Generator
4K
Probe
.01
Oscilloscope

(NOTE: Have your instructor check the circuit.)

M. Repeat Steps B through K and sketch the waveforms in the spaces provided below

1. 500 Hz

JOB SHEET #1

2. 1 KHz

3. 1.5 KHz

4. 2.0 KHz

(NOTE: The first circuit is a differentiator and the second circuit is an integrator. The waveform is dependent on the values of R, C, and frequency.)

N. Show your results to the instructor

O. Put away tools and materials

ANALOG CONTROL CIRCUITS
UNIT VI

JOB SHEET #2 — CONSTRUCT AND ANALYZE ACTIVE INTEGRATOR CIRCUIT

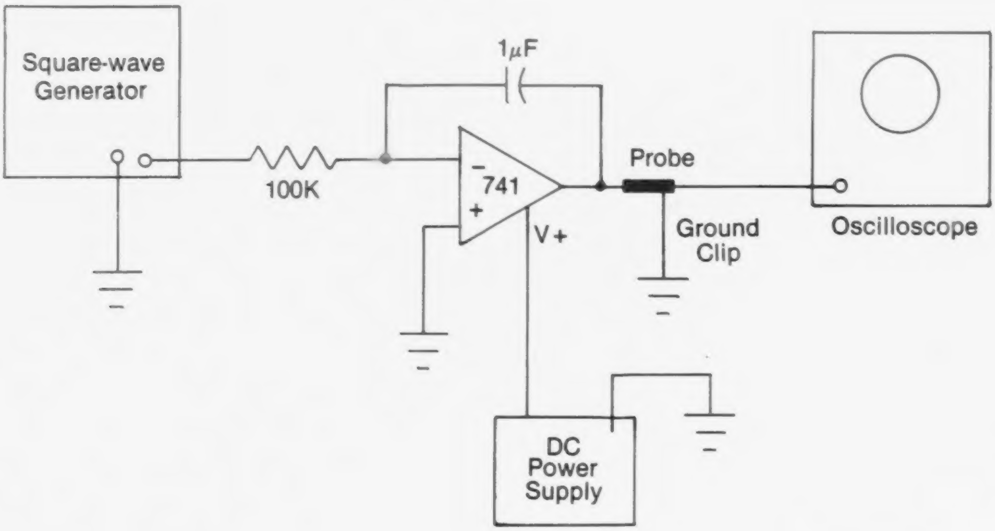
I. Tools and materials

- A. Square wave generator, variable frequency from 20 to 30 Khertz
- B. Oscilloscope with probe
- C. Resistor, 100 Kohms, ¼ watt
- D. Capacitor, 1 μF,25 volts
- E. Operational amplifier, integrated circuit type 741
- F. Breadboard
- G. Power supply, regulated, 15 VDC

II. Procedure

A. Construct the circuit shown below (Figure 13)

FIGURE 13


Square-wave Generator
1μF
100K
–
741
+
V+
Probe
Ground Clip
Oscilloscope
DC Power Supply

(NOTE: Have your instructor check the circuit.)

JOB SHEET #2

B. Adjust the power supply for 15 volts

C. Adjust the square wave generator for 500 hertz at 5 volts peak-to-peak

D. Adjust the oscilloscope for a stable display showing no more than three cycles at full-wave amplitude

E. Slowly increase the freqency output of the generator while readjusting the oscilloscope sweep rate in order to view the output of the integrator

F. Continue to increase the frequency to 25 Khertz and observe the output wavefore

G. Show the output display to the instructor

H. Put away tools and materials

ANALOG CONTROL CIRCUITS
UNIT VI

JOB SHEET #3 — CONSTRUCT AND ANALYZE A SUMMING AMPLIFIER

I. Tools and materials

  A. Multimeter with test leads

  B. Breadboard

  C Integrated circuit, type 741, operational amplifier

  D. Resistors, 1/4 watt

    1. 5.1K, 1 each

    2. 10K, 2 each

    3. 15K, 1 each

    4. 51K, 2 each

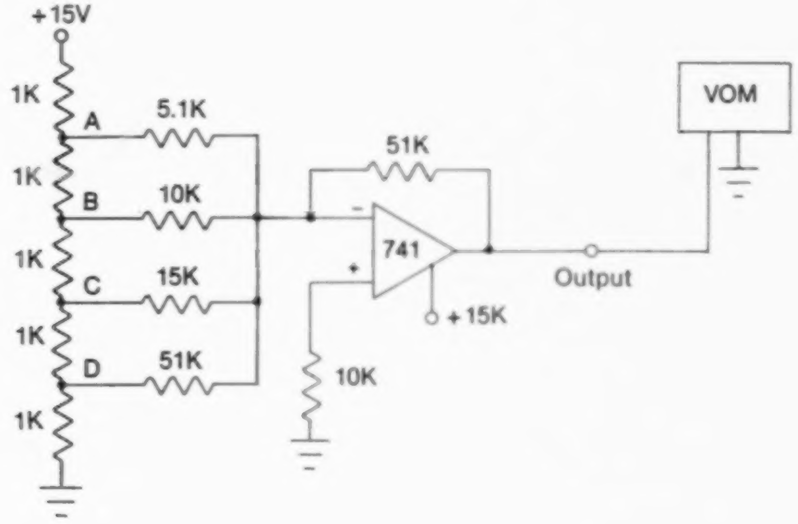
    5. 1K, 5 each

  E. Laboratory DC power supply to 15 volts, regulated

II. Procedure

  A. Construct the circuit shown below (Figure 14)

FIGURE 14


+15V
1K
1K
1K
1K
1K
A
B
C
D
5.1K
10K
15K
51K
51K
741
-
+
+15K
10K
Output
VOM

(NOTE: Have your instructor check the circuit.)

B. Adjust the power supply for 15 volts DC

C. Use the multimeter to measure the voltages at nodes A, B, C, and D

D. Record the input voltages below

Node A ______________________________

Node B ______________________________

Node C ______________________________

Node D ______________________________

E. Measure and record the output voltage below

Output ______________________________

(NOTE: The output voltage should be the sume of the products of the input voltages and their resistor ratios.)

F. Use the formula below to calculate the output voltage from the measured input voltages

$$\text{Output} = A\left(\frac{51}{5.1}\right) + B\left(\frac{51}{10}\right) + C\left(\frac{51}{14} + D\left(\frac{51}{51}\right)$$

(NOTE: the simplified equation is given below.)

$$\text{Output} = 10A + 5.1B + 3.4C + D$$

G. Record the calculated output voltage below

Calculated output ______________________________

(NOTE: The calculated value may vary from the measured output due to resistor tolerances and lack of isolation between the several inputs simulated here by a simple voltage divider.)

H. Show your results to the instructor

I. Put away tools and materials

ANALOG CONTROL CIRCUITS
UNIT VI

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with analog control circuits to their correct definitions. Write the correct numbers in the blanks provided.

______a. To connect with and make compatible for communications to other equipment

______b. Use of fluid to perform work

______c. Wires and devices arranged to control equipment by an analog signal

______d. That portion of an electrical circuit that initiates a change in the function of a device

______e. Use of light rays to transmit or signal a control function

1. Analog control circuit
2. Hydraulic
3. Optical
4. Interface
5. Control circuit

2. Select from a list characteristics of analog control circuits. Write an "X" beside each correct characteristic.

______a. Uses alternating analog/digital signal

______b. Uses steady analog control signal

______c. Slower reactive time than digital control circuits

______d. Require continuous feedback from output monitor

______e. Susceptible to induced voltage errors caused by transients

______f. Must have special equipment to interface with computers

3. List applications of analog control circuits. Give at least three different types of applications.

a. ____

____

b. ____

____

TEST

c. ____

____

4. Match types of analog control to the correct descriptions. Write the correct numbers in the blanks provided.

______a. Control by turning elements on and off as opposed to varying the amount of operation

______b. Requires operator monitoring and manipulation

______c. Controlling elements operate at any degree between off and full power

______d. System with no feedback loops required

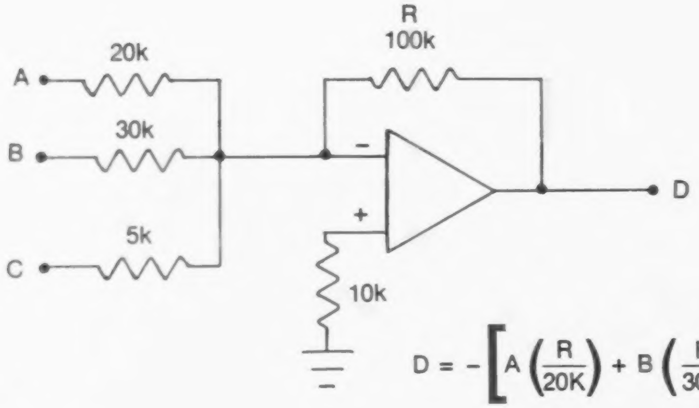
______e. Control is ordinarily accomplished without operator intervention

______f. Monitors the controlled actions and automatically adjusts control to meet system requirements

1. Open-ended (open loop) control
2. Feedback (closed loop) control
3. On/Off control
4. Variable control
5. Automatic control
6. Manual control

5. Identify analog amplifier configurations by their symbols and output formulas. choose the correct term from the list below and write it in the space provided.

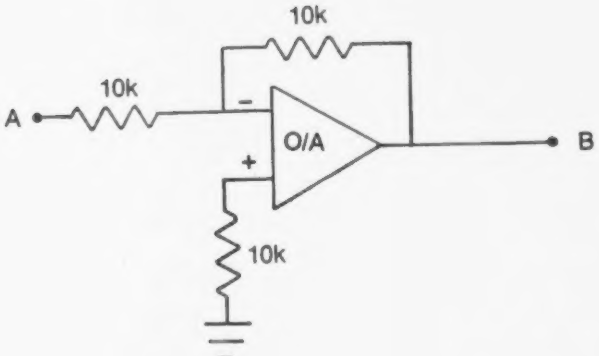
Unity gain, non-inverting
Unity gain, inverting
1+ ratio gain, non-inverting
Ratio gain, inverting
Variable gain, inverting
Combination, multipliers and summing
Integrator



$$D = -\left[A\left(\frac{R}{20K}\right) + B\left(\frac{R}{30K}\right) + C\left(\frac{R}{5K}\right)\right]$$

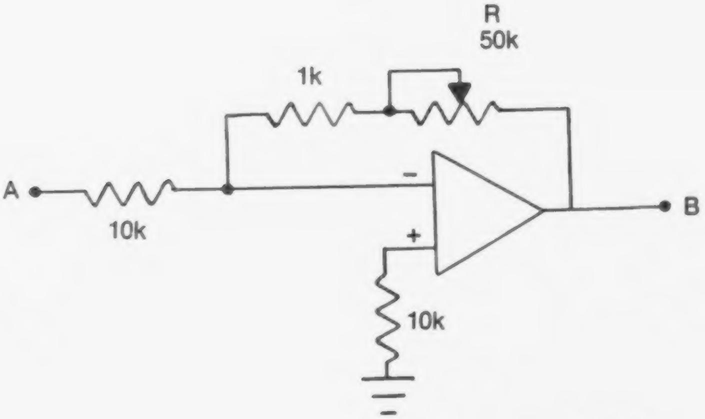
a. ____

TEST


10k
10k
A
–
+
O/A
B
10k

B = –A

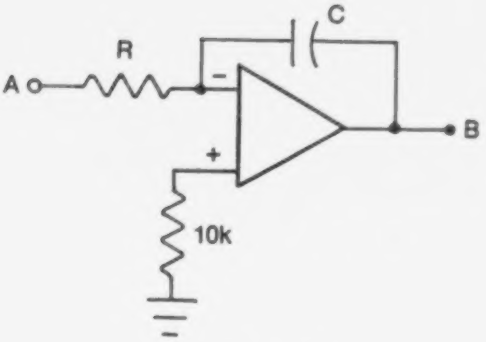
b. ____________________


R
50k
1k
A
10k
–
+
B
10k

$B = (-\frac{1k + R}{10k})A$

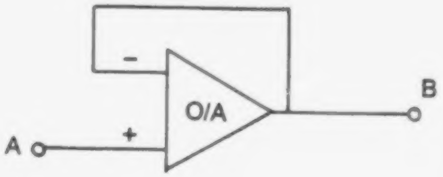
c. ____________________

TEST



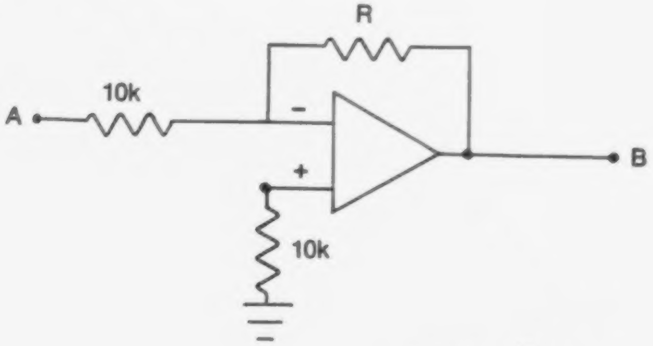
B = f(t,A,R,C)

d. ____



B = A

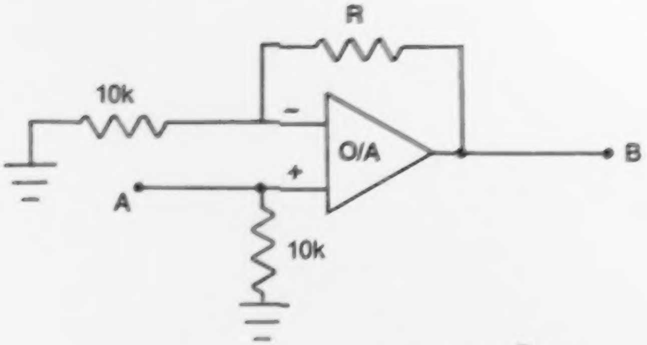
e. ____



$B = (1 - \frac{R}{10k})A$

f. ____

TEST

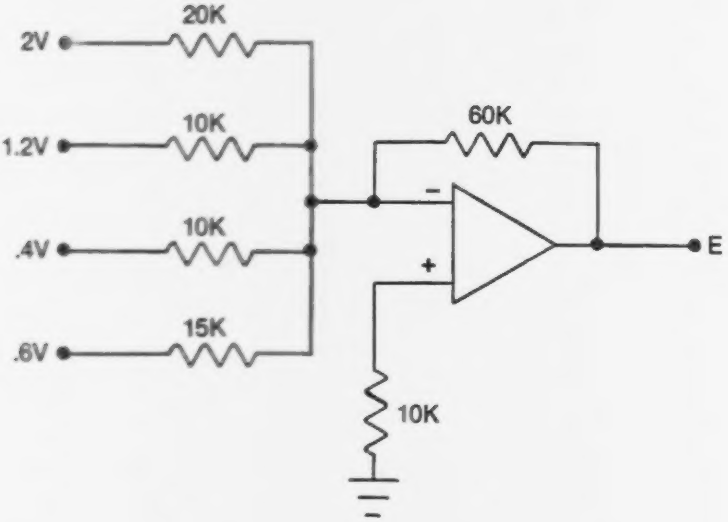

R
10k
O/A
B
A
10k

$$B = \left(1 + \frac{R}{10k}\right)A$$

g. ____

6. Determine the output of the combination multiplier and summing amplifier shown below. Show your work and write your answer in the space provided.

   Output = ______________________________


2V
20K
1.2V
10K
60K
.4V
10K
E
.6V
15K
10K

TEST

(NOTE: Test items 7 and 8 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

7. Classify types of control systems.

8. Demonstrate the ability to

   a. Construct and analyze passive integrating and differentiating analog circuits.

   b. Construct and analyze an active integrator circuit.

   c. Construct and analyze a summing circuit.

ANALOG CONTROL CIRCUITS
UNIT VI

ANSWERS TO TEST

1. a. 4
   b. 2
   c. 1
   d. 5
   e. 3

2. b, c, e, f

3. Answer may include any three of the following

   a. Convert transducer or sensor output into usable voltage or current signal
   b. Manipulate measured values representing pressures, flows, temperatures, etc. to mathematically combine them to control complex systems
   c. Ensure safe operation of systems
   d. Provide signals for monitoring and recording

4. a. 3
   b. 6
   c. 4
   d 1
   e 5
   f 2

5. a. Combination, multipliers and summing
   b. Unity gain, inverting
   c. Variable gain, inverting
   d. Integrator
   e. Unity gain, non-inverting
   f. Ratio gain, inverting
   g. 1+ratio gain, non-inverting

6. Output = -18 volts

7. Evaluated to satisfaction of instructor.

8. Performance skills evaluated to satisfaction of instructor.

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

UNIT OBJECTIVE

After completing this unit, the student should be able to design and construct a digital control circuit and determine a maintenance plan for electronic systems. The student will show this knowledge by completing assignment sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with digital control circuits to their correct definitions.
2. Describe types of signals used in control circuits.
3. Name control circuit structures.
4. Select from a list components of digital control equipment.
5. Name types of control circuit hardware.
6. Select from a list types of microprocessor-based control circuits.
7. List factors to consider in planning maintenance.
8. Recommend maintenance strategies.
9. Design and construct a digital control circuit.

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information and assignment sheets.

   C. Discuss unit and specific objectives

   D. Discuss information and assignment sheets.

   E. Visit with local industries to determine realistic problems for Assignment Sheet #6.

   (NOTE: You may want students to do the assignment individually or in groups.)

   F. Tour a facility that utilizes a microprocessor control system.

   G. Discuss pertinent and related articles in trade journals.

   H. Give test.

   I. Critique test.

   J. Reteach if necessary.

II. Instructional material

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Assignment sheets

      1. Assignment Sheet #1 — Identify Subsystems in a Block Diagram

      2. Assignment Sheet #2 — Distinguish Between Digital and Analog Components

      3. Assignment Sheet #3 — Distinguish Between Open-Loop and Closed-Loop Systems

      4. Assignment Sheet #4 — Analyze Maintenance Requirements

SUGGESTED ACTIVITIES

5. Assignment Sheet #5 — Report on Maintenance Needs for an Installed Digital Control System

6. Assignment Sheet #6 — Design and Construct a Digital Control Circuit

E. Answers to assignment sheets

F. Test

G. Answers to test

III. Unit references

A. Schmitt, Neil M. *Understanding Electronic Control of Automation Systems.* Texas Instruments Learning Center, Dallas, TX, 1983.

B. Knisley, Joseph. "Office Tower Builds in Electric Energy Efficiency," ECM Magazine, June 1984, p. 76.

C. Malvins, Albert Paul. *Digital Computer Electronics*, 2nd ed. New York: McGraw-Hill Books, 1983.

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

INFORMATION SHEET

I. Terms and definitions

A. Controller — The element in a process control loop that evaluates the controlled variable error and initiates corrective action by sending a signal to the controlling variable

B. Closed loop system — A control system in which the output is fed back and compared to the input to generate an error signal that can be used to modify the output signal

C. Open loop system — A control system whose output is a function of only the inputs to the system

D. Process controller — Controller that controls a continuously variable process that requires constant monitoring and continual updating of inputs and outputs in order to maintain a precise setpoint

E. Sequence controller — Controller that performs ON/OFF control functions in relation to time

F. Sensor — An energy conversion device which measures some physical quantity and converts it to an electrical quantity

G. Discrete sensors — Sensors that provide ON/OFF indications only

H. Mean-time-between-failure (MTBF) — The average time, usually expressed in hours, that a component or system will operate from one failure to the next

I. Mean-time-to-repair (MTTR) — The average time required to diagnose and repair a failed system

J. Signal conditioning — Changing or altering the output of I/O devices so that the signals are in a form to be acted on by electronic circuitry

K. Process variable — Any process parameter which can change values

L. Machine language — The lowest level programming language whose coded instructions consist of a string of binary digits

M. Assembly language — An abbreviated computer language using mnemonics which humans can use to program computers

N. Distributed digital control (DDC) — The use of controllers strategically placed in a structure, each of which has the capability of performing detailed control functions directly with its own microprocessor

O. Automatically programmed tools (APT) — Language that is used to control the positioning and movement of a machine tool

INFORMATION SHEET

II. Types of signals in control circuits

  A. Digital — Binary representation

  B. Analog — Varies in amplitude, frequency, and phase

III. Structures of control circuits

  A. Open loop systems

  B. Closed loop systems

IV. Components

  A. Sensors

    1. Continuous process

EXAMPLES:
a. Flow
b. Temperature
c. Pressure
d. Velocity
e. Acceleration

    2. Intermittent

EXAMPLES:
a. Level
b. Composition
c. Weight
d. Volume
e. Tension
f. Compression
g. Position
h. Dimension

    3. Discrete

(NOTE: Discrete sensors measure the on/off condition of a component.)

  B. External inputs

(NOTE: External inputs are normally directed by a human operator.)

EXAMPLES: Emergency shutdown, change speed, alter control of a process

  C. Signal conditioning (input and output)

EXAMPLES: Amplification, filtering, and other wave-shaping

INFORMATION SHEET

D. Actuators

1. Continual operation

EXAMPLES: Flow control valves, pumps, positioning drives

2. Intermittent operation

EXAMPLES: Variable speed drives, clutches, brakes

3. Discrete operation

EXAMPLES: Solenoids, stepping motors, stepping switches, power relays

E. External outputs

EXAMPLES: CRT, meter, printer, bell, light

F. Controller

(NOTE: Controllers receive input from sensors and external devices, perform math calculations and logical comparisons, and then decide what to do next. It then generates control signals.)

EXAMPLES:
a. Amplifiers
b. Filters
c. Digital circuits
  1) Logic devices
  2) Microprocessors
  3) Memory or pattern devices

V. Control system hardware

A. Controllers

1. Sequence controller (ON/OFF)

2. Process controller

a. Provides an output which can vary from full-on to full-off

b. Usually performs math calculations

B. Sensors

1. Process control

a. Temperature

EXAMPLES: Thermocouple, thermistor

INFORMATION SHEET

b. Pressure

EXAMPLES: Aneroid barometer, capacitive pressure

c. Flow

EXAMPLE: Venturi, turbine

2. Discrete

a. Position sensors

EXAMPLES: Light sensor, capacitive switch, hall-effect switch

b. Image sensors

C. Actuators

1. Solenoid

2. Relay

3. Motor

EXAMPLES: a. D.C. servo
b. A.C. synchronous
c. Universal
d. Stepping

VI. Microprocessor-based control circuits

A. Software/programming languages

1. Instructions

2. Machine language

3. Assembly language

4. High-level languages

EXAMPLES: APT language, FORTRAN

B. Continuous control systems

1. Microcomputer-based controller

2. Dedicated process controller

C. DDC — Distributed digital control

D. DNC — Distributed numerical control

INFORMATION SHEET

VII. Factors to consider in planning maintenance

A. Reliability of components

1. Affected by wear and tear of mechanical parts and defective equipment

   (NOTE: Most electronic failures result from bad solder joints or loose connections.)

2. Increased by electronic control

3. Decreased by poor operating practices

4. Increased by effective preventive maintenance

B. Failure rate

1. High in component infancy

2. Level during operational life

3. Increases towards end of life

C. MTBF (Mean-time-between-failures)

1. Given as statistical average for a component or equipment based on historical failure rate

2. Increased with preventive maintenance

D. MTTR (Mean-time-to-repair)

1. Given as a statistical average for time from failure to return to operation

2. Replacing subsystem leads to lowest MTTR

3. Chip or component level troubleshooting causes high MTTR

E. Product availability ($PA = \frac{MTBF}{MTBF + MTTR} \times 100$)

1. Ratio of total life of a product to the time it is actually available

2. Useful when semiconductors are involved

INFORMATION SHEET

EXAMPLE: A control system with twenty relays of the same type in operation for one eight hour shift per day. Relay MTBF = 1000 hours. System MTBF = 50 hours

Component MTBF = 1000 hours

$$\text{System MTBF} = \frac{\text{Component MTBF}}{\text{\# of Components}} \times 100$$

(NOTE: System MTBF is usually used.)

$$\text{PA} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \times 100$$

EXAMPLE: Component MTBF = 1000 hours

$$\text{System MTBF} = \frac{1000}{20} = 50 \text{ hours}$$

Time to repair = 2 hours

$$\text{PA} = \frac{50}{50 + 2} \times 100$$

$$\text{PA} = \frac{50}{52} \times 100 = 96\%$$

PA = 96%

F. Methods of maintenance

EXAMPLES:
1. Fault indicators
2. Self-tests
3. Step-by-step operations
4. Swap sub-assemblies, or entire system if possible, rather than troubleshoot to component level

G. Costs of repair/replacement versus costs of lost time and inventory investments

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

ASSIGNMENT SHEET #1 — IDENTIFY SUBSYSTEMS IN A BLOCK DIAGRAM

NAME ______________________________ SCORE ______________

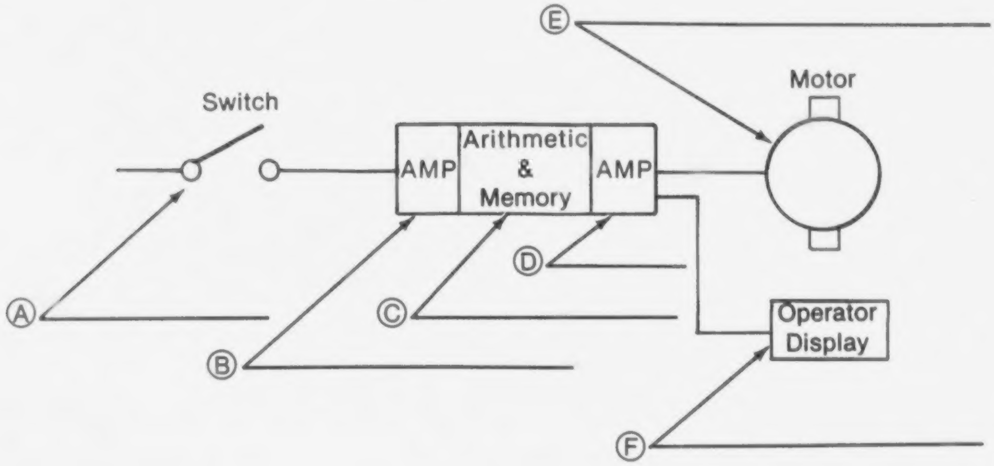
An industrial technician must understand the role of each subsystem and component in the operation of a total system in order to perform required maintenance and monitor proper operation. Thus, skill in reading a block diagram is vital.

Label the diagram with the appropriate subsystem or component name.

Components:

- Signal conditioning
- Sensors
- Actuators
- External inputs
- External outputs
- Controller

(NOTE: Some components may be used twice.)



DIGITAL CONTROL AND MAINTENANCE
UNIT VII

ASSIGNMENT SHEET #2 — DISTINGUISH BETWEEN DIGITAL AND ANALOG COMPONENTS

NAME ______________________________ SCORE ______________

An industrial technician must understand the types of sensing and control required in system operations and whether digital or analog signals are more appropriate for each type of system.

Associate the following components with (A) analog or (D) digital signals.

1. ________ Switch
2. ________ Temperature
3. ________ Relay
4. ________ Stepping motor
5. ________ LED readout
6. ________ Meter needle indication
7. ________ Fault light
8. ________ Pressure gauge

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

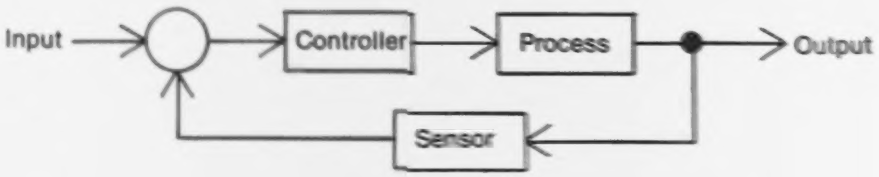
ASSIGNMENT SHEET #3 — DISTINGUISH BETWEEN OPEN-LOOP AND CLOSED-LOOP SYSTEMS

NAME ________________________________ SCORE ______________

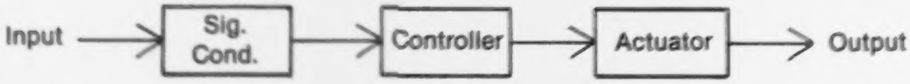
A major consideration in the functioning of asystem is whether its operation is closed-loop or open-loop. Malfunctions can be in sensors or actuators, and proper analysis by the technician is essential.

1. Identify the following diagrams as either (OL) open-loop or (CL) closed-loop systems.

   a. ____________


Input
Controller
Process
Output
Sensor

   b. ____________


Input
Sig. Cond.
Controller
Actuator
Output

2. a. A pump that switches on once each hour and runs for 15 minutes is an example of a/an ____________ loop system.

   b. A variable speed pump that adjusts flow to meet changes in demand is an example of a/an ____________ loop system.

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

ASSIGNMENT SHEET #4 — ANALYZE MAINTENANCE REQUIREMENTS

NAME ______________________________ SCORE ____________

In the world of industry, time and money can make or break a company. The industrial technician must be sure that equipment is up and operating so that production can continue and the company can operate. It would be nice if a company could afford to have twice as much equipment as they need so that if one machine went down the operator could just move to another and production would never be interrupted. Obviously, such an investment is generally not realistic. Just as obvious is the fact that no company wants to have a machine down for two days awaiting delivery of a two-dollar part that takes 15 minutes to install, especially if that part must be replaced a couple of times a year. For these reasons, MTBF and MTTR are given a great deal of consideration when deciding which repair parts should be kept on-hand at the company, how many of each part, the size and skills of the maintenance staff, and other decisions.

Assume that you are the chief maintenance technician for a plant that manufactures household appliances. One of your tasks is to study MTBF and MTTR figures to determine the inventory of spare parts and equipment. Study the situations below and make recommendations for maintenance. Discuss your decisions with your instructor.

1. The sheet metal for the appliances is formed with a numerically controlled press. In the electronic circuitry, the most likely component to fail is a relay switch with an MTBF of 2000 hours. Each press contains four of this particular relay, and the plant has three sheet metal presses. It takes one hour to replace the relay. If the part must be ordered, average time before delivery is 22 hours. The relay costs $48 each, or $37 when 25 or more are purchased.

   a. What is the PA if the part is in stock? ____________

   b. What is the PA if the part is not in stock? ____________

   c. What would you recommend with regard to keeping spare relays on hand? ____

   d. Would you recommend that the relays be replaced before failure as part of a preventive maintenance program? ____

ASSIGNMENT SHEET #4

2. The appliance sheet metal is painted in a special dust-free room prior to assembly. Mixing of the paints and thinners is done by computer to maintain a constant viscosity. The sensing subsystem has a MTBF of 6000 hours. The subsystem is comprised primarily of transistors with an MTBF of 10,000 hours and integrated circuits with an MTBF of 50,000 hours. The time required to replace the subsystem is four hours. The average time spent to troubleshoot and repair a defective subsystem is 18 hours. If a spare subsystem is not in stock it takes approximately 10 hours to receive one, at a cost of $1800. The transistors and ICs average less than $5 each and most are available within two hours.

   a. What maintenance strategy would you recommend? ______________________

   ____

   ____

   b. What parts, if any, would you keep on hand and in what quantities? ________

   ____

   ____

3. The drying room for painted sheet metal is maintained at a constant temperature and humidity level. Adjustments are made by a computer. In the electronic circuitry, the temperature sensing subsystem has a MTBF of 8000 hours and the humidity sensing subsystem has a MTBF of 5000 hours. It takes approximately 2 hours to replace either system. Manual control of temperature and humidity is possible if the automatic sensors fail. Cost of the temperature sensing subsystem is $1250 and of the humidity sensing subsystem is $2600. Delivery time on either subsystem requires about 23 hours. Troubleshooting and local repair averages about 14 hours on either subsystem.

   a. What maintenance strategy would you recommend for these subsystems? Be sure to specify which subsystem if the strategies differ. __________________

   ____

   ____

   ____

   b. What is the PA of the temperature sensing subsystem if the part must be ordered? ____

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

ASSIGNMENT SHEET #5 — REPORT ON MAINTENANCE NEEDS FOR AN INSTALLED INDUSTRIAL DIGITAL CONTROL SYSTEM

NAME ______________________________ SCORE ______________

With your instructor's assistance, visit a plant that uses digital control systems or locate an article from a trade magazine that describes the operation of a digital control system. Write a summary of the system, the controller, and the uses of the system. Your report should include a description of the system and a statement as to whether it is open or closed. Also you should consider the factors studied in this unit, such as the maintenance schedule for the system, the approaches used in stocking repair parts, the level of repair used, and figures for MTBF, MTTR, and PA.

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

ASSIGNMENT SHEET #6 — DESIGN AND CONSTRUCT A DIGITAL CONTROL CIRCUIT

NAME ______________________________ SCORE ______________

By this point in your training you have studied and performed many of the tasks required of an industrial maintenance technician working in the electronics specialty area. The other two important duties expected of such technicians are troubleshooting and the design of simple monitoring and controlling systems. Troubleshooting will be covered in the final section of this manual. This assignment will give you a chance to design and construct a digital control circuit.

1. Visit with your instructor to discuss industrial applications of digital control. The two of you will determine a realistic industrial requirement for digital control that an industrial maintenance technician might design and install in a plant.

2. Design a digital control system that will solve the digital control problem you and your instructor determined.

   Consider cost, efficiency, product availability, maintenance, and other design considerations that you have studied.

3. Draw the diagram of your circuit on the back of this sheet and discuss the circuit with your instructor.

4. Construct the system you have designed and have your instructor inspect it prior to applying power.

5. Operate the circuit and analyze its effectiveness.

6. Write a short report on the effectiveness of your design and make recommendations for changes and for a maintenance strategy.

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. External inputs

B. Signal conditioning

C. Controller

D. Signal conditioning

E. Actuator

F. External output

Assignment Sheet #2

1. D
2. A
3. D
4. D
5. D
6. A
7. D
8. A

Assignment Sheet #3

1. a. Closed-loop
   b. Open-loop
2. a. Closed-loop
   b. Open-loop

Assignment Sheets #4, #5, and #6 — Evaluated to the satisfaction of the instructor.

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with digital control circuits to their correct definitions. Write the number of the term in the blank provided.

______a. Language that is used to control the positioning and movement of a machine tool

______b. An abbreviated computer language using mneumonics which humans can use to program computers

______c. A control system in which the output is fed back and compared to the input to generate an error signal that can be used to modify the output signal

______d. The element in a process control loop that evaluates the controlled variable error and initiates corrective action by sending a signal to the controlling variable

______e. The use of controllers strategically placed in a structure, each of which has the capability of performing detailed control functions directly with its own microprocessor

______f. Sensors that provide ON/OFF indications only

______g. The lowest level programming language whose coded instructions consist of a string of binary numbers

______h. The average time, usually expressed in hours, that a component or system will operate from one failure to the next

______i. The average time required to diagnose and repair a failed system

______j. A control system whose output is a function of only the inputs to the system

______k. Controller that controls a continuously variable process that requires constant monitoring and continual updating of inputs and outputs in order to maintain a precise setpoint

1. Controller
2. Closed-loop system
3. Open-loop system
4. Process controller
5. Sequence controller
6. Sensor
7. Discrete sensors
8. Mean-time-to-repair (MTTR)
9. Mean-time-between-failure (MTBF)
10. Signal conditioning
11. Process variable
12. Assembly language
13. Distributed digital control (DDC)
14. Machine language
15. Automatically programmed tools (APT)

TEST

_____l. Any process parameter which can change values

_____m. Controller that performs ON/OFF control function in relation to time

_____n. An energy conversion device which measures some physical quantity and converts it to an electrical quantity

_____o. Changing or altering the output of I/O devices so that the signals are in a form to be acted on by electronic circuitry

2. Describe types of signal control. Write your answers in the space provided.

   a. Digital — ____

   ____

   b. Analog — ____

   ____

3. Name the two types of control circuit structures. Write your answers in the space provided.

   a. ____________________

   b. ____________________

4. Select from a list components of digital control equipment. Write an "X" beside each correct component.

_____a. Sensors

_____b. Summing circuit

_____c. External inputs

_____d. Signal conditioning

_____e. Actuators

_____f. Integrator/differentiator

_____g. External outputs

_____h. Controller

TEST

5. Name types of control circuit hardware. Write your answers in the space provided.

   a. ______________________

   b. ______________________

   c. ______________________

6. Select from a list types of microprocessor-based control circuits. Write an "X" beside each correct answer.

   _____a. Analog conversion

   _____b. Software/programming languages

   _____c. Discrete sensor

   _____d. Continuous control systems

   _____e. Distributed digital control

   _____f. Distributed analog control

   _____g. Distributed numerical control

7. List at least four factors to consider in planning maintenance. Write your answers in the spaces provided.

   a. ____

   b. ____

   c. ____

   d. ____

(NOTE: Test items 8-13 list the assignment sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

8. Identify subsystems in a block diagram.

9. Distinguish between digital and analog components.

10. Distinguish between open-loop and closed-loop systems.

11. Analyze maintenance requirements.

12. Report on maintenance needs for an installed industrial digital control system.

13. Design and construct a digital control circuit.

DIGITAL CONTROL AND MAINTENANCE
UNIT VII

ANSWERS TO TEST

1. a. 15
   b. 12
   c. 2
   d. 1
   e. 13
   f. 7
   g 14
   h. 9
   i. 8
   j. 3
   k. 4
   l. 11
   m. 5
   n. 6
   o. 10

2. a. Digital — Binary representation
   b. Analog — Varies in amplitude, frequency, and phase

3. a. Closed loop
   b. Open loop

4. a, c, d, e, g, h

5. (In any order)

   a. Controllers
   b. Sensors
   c. Actuators

6. b, d, e, g

7. (Answer should include any four of the following)

   a. Reliability of components
   b. Failure rate
   c. MTBF
   d. MTTR
   e. Product availability
   f. Methods of maintenance
   g. Costs of repair/replacement versus costs of lost time and inventory investments

8. Evaluated to the satisfaction of instructor.

9. Evaluated to the satisfaction of instructor.

ANSWERS TO TEST

10. Evaluated to the satisfaction of instructor.

11. Evaluated to the satisfaction of instructor.

12. Evaluated to the satisfaction of instructor.

13. Evaluated to the satisfaction of instructor.

TROUBLESHOOTING
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to analyze a malfunctioning system and troubleshoot down to a component of that system. The student will show this knowledge by completing assignment sheet, job sheet, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with troubleshooting to their correct definitions.
2. State meaning of symbols and abbreviations used in troubleshooting.
3. Label types of block diagrams.
4. Determine sub-assemblies that may be at fault by analyzing a block diagram and listed symptoms.
5. Demonstrate the ability to troubleshoot various electronic circuits.

TROUBLESHOOTING
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheets.

   C. Provide students with information, assignment, and job sheets.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet and assignment sheets with transparencies.

   F. Demonstrate and discuss procedures outlined in the job sheets.

   G. Show one or more maintenance manuals with troubleshooting sections.

   H. Demonstrate how to troubleshoot.

   I. Obtain several meters and other troubleshooting equipment and demonstrate their use.

   J. Use an overhead projector and the transparencies from this unit to illustrate flowcharting, block diagram analysis, resistor networks, test equipment, and troubleshooting motors.

   K. Demonstrate the use of maintenance manual, parts-illustration manual, and maintenance history log books to help diagnose a hardware failure.

   L. Provide students with faulty circuits such as those used in any of the previous units of this and other books in the series; the competency profile for this book includes a list of possible circuits to use.

   M. Give test.

   N. Critique test.

   O. Reteach, if necessary.

II. Instructional material

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

SUGGESTED ACTIVITIES

D. Transparency masters

   1. TM #1 — Block Diagrams
   2. TM #2 — Troubleshooting
   3. TM #3 — System Networks
   4. TM #4 — System Networks (Con'd.)

E. Assignment Sheet #1 — Determine Subassemblies that may be at Fault by Analyzing a Block Diagram and Listed Symptoms

F. Answers to Assignment Sheet

G. Job Sheet #1 — Complete Troubleshooting Procedures

H. Test

I. Answers to test

III. Unit references

A. Grob, Bernard. *Basic Electronics,* Fourth edition, New York; McGraw-Hill Books, 1977.

B. Dungan, Frank R. *Linear Integrated Circuits for Technicians.* Belmont, California; Wadsworth Inc., 1984.

C. Hall, Douglas V. *Microprocessors and Digital Systems*, New York; McGraw-Hill Books, 1983.

D. Kershaw, John D. *Digital Electronics Logic and Systems*, Belmont, California; Wadsworth Inc., 1983.

TROUBLESHOOTING
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Block diagram — A diagram of system blocks, sub-units, or procedures that may be used for troubleshooting

B. Short circuit — A circuit that bypasses current around a component or components due to the failure of another component or the accidental bridging of two conductors

C. Open circuit — A circuit that has current flow blocked due to a component failure or broken conductor device

D. Multimeter — Analog or digital device for voltage, current, and resistance measurements

E. Clamp-on ammeter — A meter that is clamped around a line to determine current in that line

F. Signal injection — The injection of a signal within a system to isolate a malfunction to a sub-system

G. Chart recorder — A device that senses voltage or current or spikes and records the measurements on a strip of paper

H. Diagnostics — A routine performed to check electronic circuits

I. Service manual (Maintenance manual) — A manual for a specifc machine that aids in troubleshooting, ordering parts, assembly, and disassembly of sub-systems

J. Subassembly — Parts of a complete unit that can operate together to produce a specific outcome

K. Leakage — A partial short that occurs under high voltage conditions

L. Flowchart — Map of a logical sequence of events that leads to a possible solution to a problem

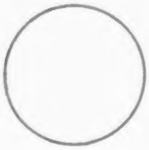
(NOTE: Flow charts are commonly used in troubleshooting to describe the procedure for isolating problems.)

II. Symbols and abbreviations

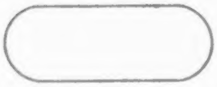
A. DVM — Digital voltmeter

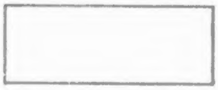
INFORMATION SHEET

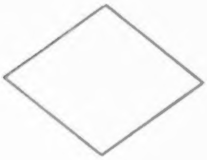
B. — Denotes a test point

C. 

or — Flowchart symbols for a manual function of an interruption of an automatic operation



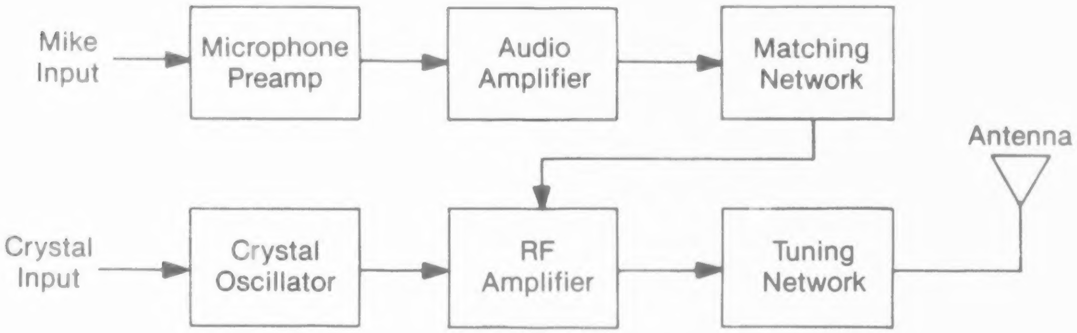
D.  — Flowchart symbol for process or function

E.  — Flowchart symbol for decision or test results

III. Types of block diagrams (Figures 1-3)

A. Circuit assembly

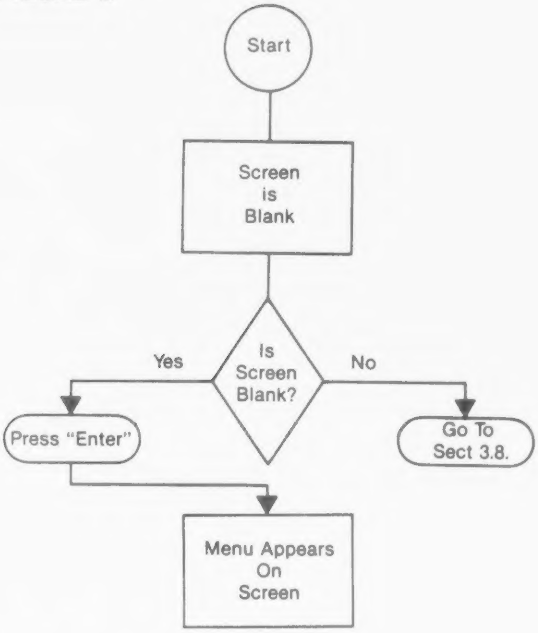
FIGURE 1


Mike Input
Microphone Preamp
Audio Amplifier
Matching Network
Antenna
Crystal Input
Crystal Oscillator
RF Amplifier
Tuning Network

INFORMATION SHEET

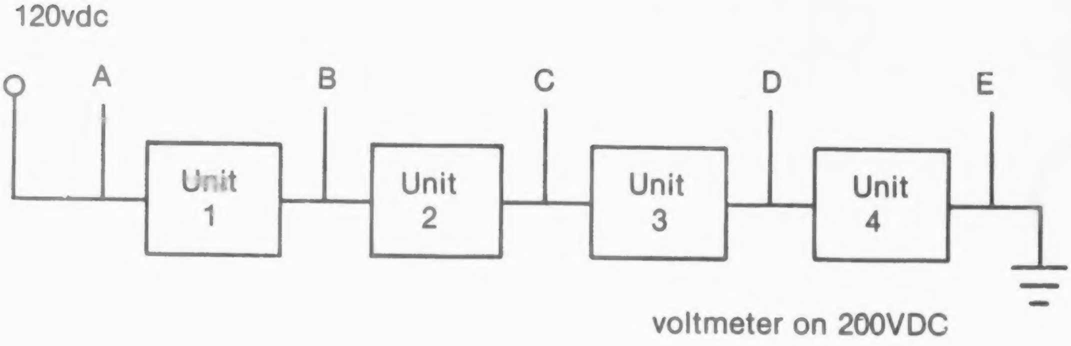
B. Flowchart

FIGURE 2


Start
Screen is Blank
Is Screen Blank?
Yes
No
Press "Enter"
Go To Sect 3.8.
Menu Appears On Screen

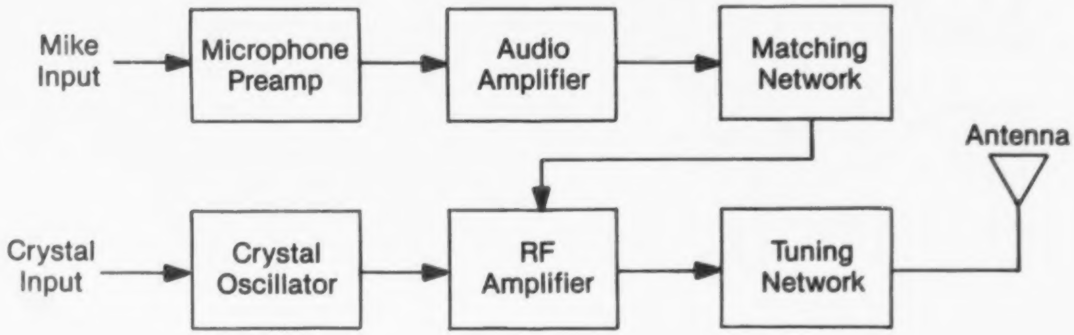
C. System network

FIGURE 3

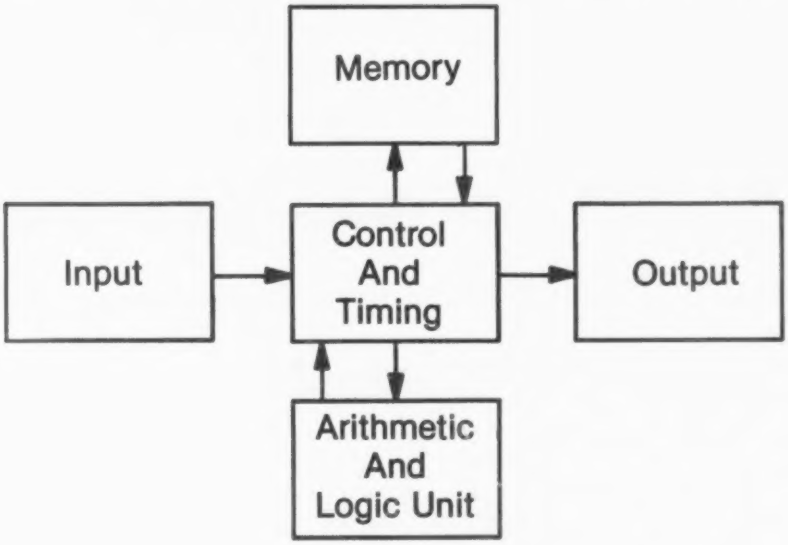

120vdc
A
B
C
D
E
Unit 1
Unit 2
Unit 3
Unit 4
voltmeter on 200VDC

Block Diagrams

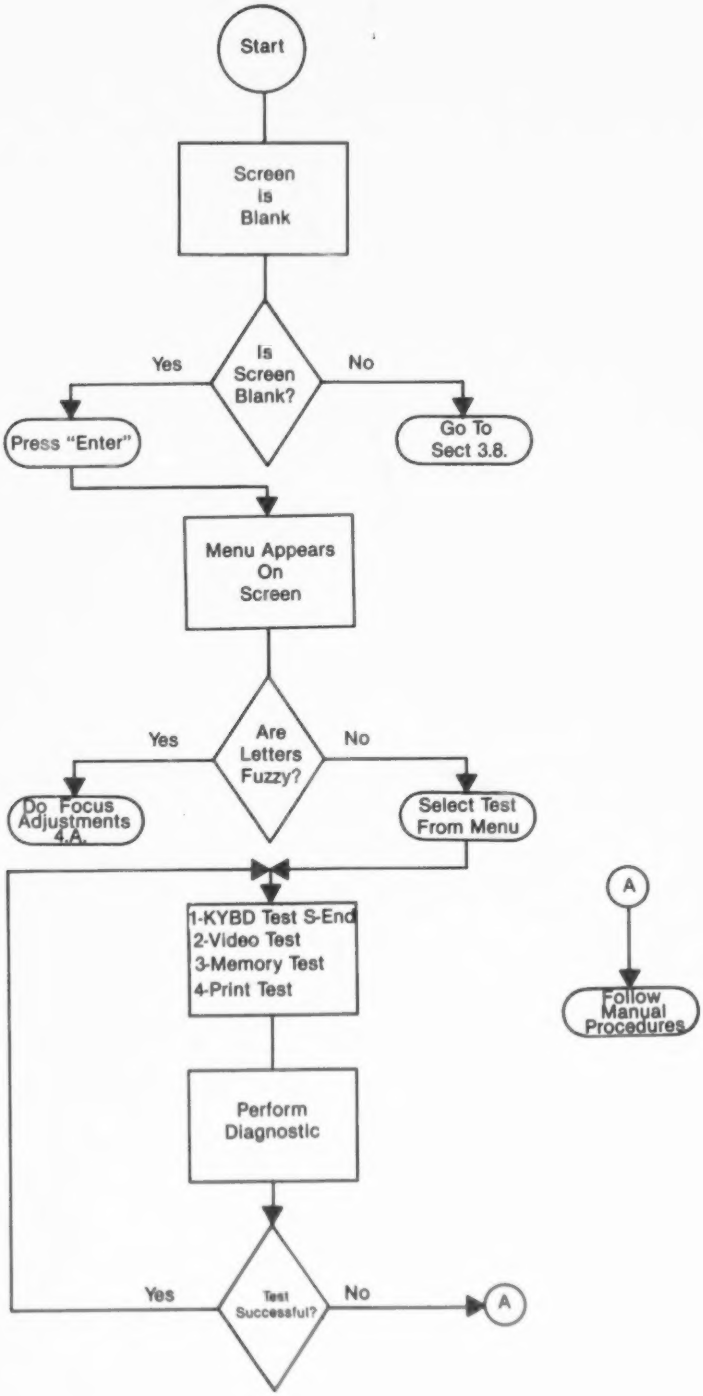
Block Diagram of an AM Transmitter


Mike Input
Microphone Preamp
Audio Amplifier
Matching Network
Antenna
Crystal Input
Crystal Oscillator
RF Amplifier
Tuning Network

Major Blocks of A Digital Computer

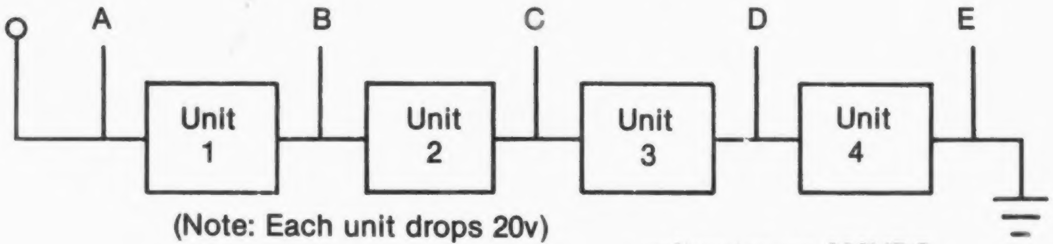

Memory
Input
Control And Timing
Output
Arithmetic And Logic Unit

Troubleshooting Flowchart


Start
Screen is Blank
Is Screen Blank?
Yes
No
Press "Enter"
Go To Sect 3.8.
Menu Appears On Screen
Are Letters Fuzzy?
Yes
No
Do Focus Adjustments 4.A.
Select Test From Menu
1-KYBD Test S-End
2-Video Test
3-Memory Test
4-Print Test
Perform Diagnostic
Test Successful?
Yes
No
A
A
Follow Manual Procedures

System Networks

*120vdc

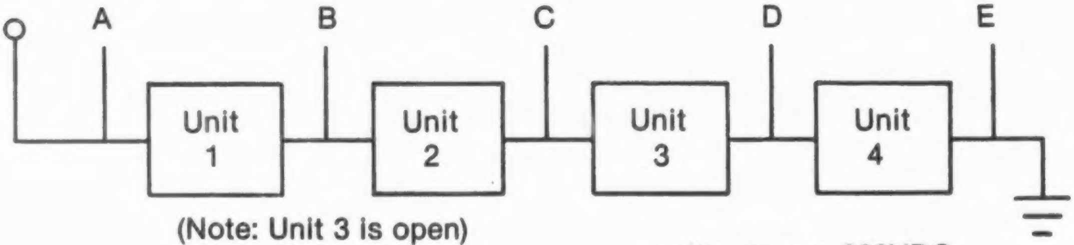

A
B
C
D
E
Unit 1
Unit 2
Unit 3
Unit 4

(Note: Each unit drops 20v)

voltmeter on 200VDC

Red Lead \ Test Point	A	B	C	D	E
A	0v	30v	60v	90v	120v
B	-30v	0v	30v	60v	90v
C	-60v	-30v	0v	30v	60v
D	-90v	-60v	-30v	0v	30v
E	-120v	-90v	-60v	-30v	0v

*120vdc Open circuit:


A
B
C
D
E
Unit 1
Unit 2
Unit 3
Unit 4

(Note: Unit 3 is open)

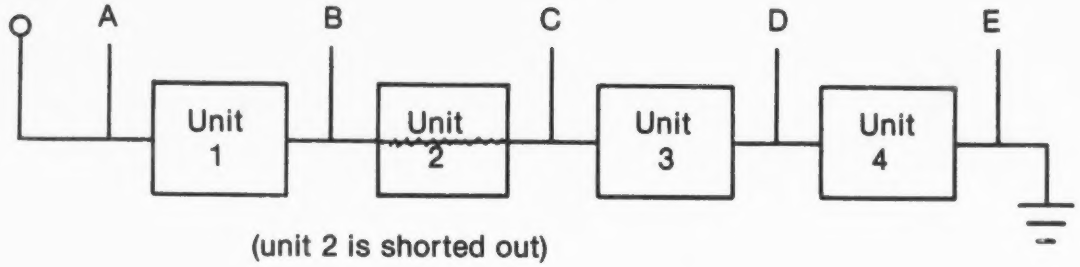
voltmeter on 200VDC
(Note: Change always occurs between C & D)

Red Lead \ Black Lead	A	B	C	D	E
A	0v	0v	0v	120v	120v
B	0v	0v	0v	120v	120v
C	0v	0v	0v	120v	120v
D	-120v	-120v	-120v	0v	0v
E	-120v	-120v	-120v	0v	0v

System Networks

Short circuit:

120vdc



(unit 2 is shorted out)

A short removes some or all resistance from total rests

Three remaining units share load 120v ÷ 3 = 40v

Red Lead \ Black Lead	A	B	C	D	E
A	0v	40v	40v	80v	120v
B	-40v	0v	0v	40v	80v
C	-40v	0v	0v	40v	80v
D	-80v	-40v	-40v	0v	40v
E	-120v	-80v	-80v	-40v	0v

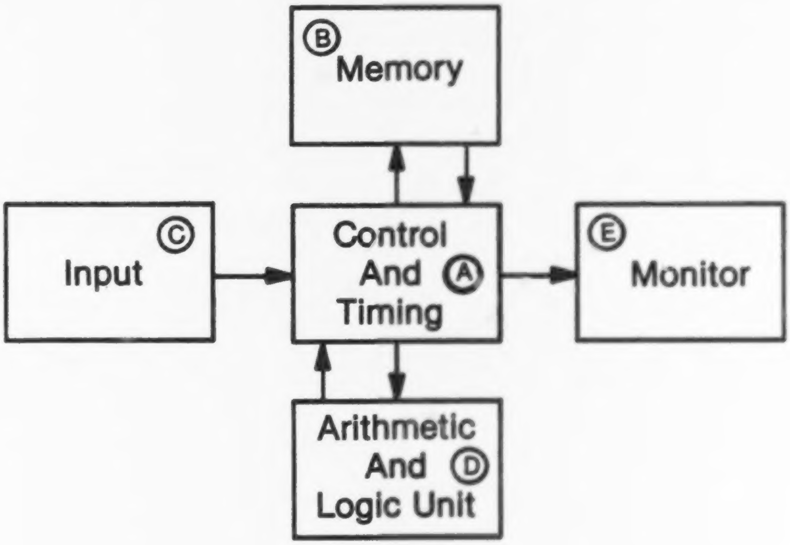
(Note: Voltage readings between Points B & C are equal)

TROUBLESHOOTING
UNIT I

ASSIGNMENT SHEET #1 — DETERMINE SUBASSEMBLIES THAT MAY BE AT FAULT BY ANALYZING A BLOCK DIAGRAM AND LISTED SYMPTOMS

NAME ______________________________ SCORE ____________

One key to troubleshooting is the ability to narrow down the number of possible problems by determining which subassemblies could lead to the malfunctions being experienced.



Read the following and determine which subassembly is probably faulty. Complete the statements with the letter of the suspected subassembly.

1. All register indicators OK. Power supply voltages OK. Memory diagnostics run but no readouts on monitor screen. Monitor screen is dark. The failing unit is ____________.

2. All readouts normal except when performing a subtraction function. Register indicators look normal on control and timing unit. The failing unit is ____________.

3. All diagnostic programs run good when loaded in from the tape unit. Disk drive will not load programs but store data OK. The failing unit is ____________.

4. The machine halts during power up sequence. The register indicators show a memory read/write error according to the maintenance manual. The failing unit is ____________.

5. No input accepted and no output observed. Register indicators show no activity. All switches on and power supply normal. The failing unit is ____________.

TROUBLESHOOTING
UNIT I

ANSWERS TO ASSIGNMENT SHEET

1. E
2. D
3. C
4. B
5. A

TROUBLESHOOTING
UNIT I

JOB SHEET #1 — TROUBLESHOOT VARIOUS ELECTRONIC CIRCUITS

I. Tools and equipment

A. Electronic circuits provided by the instructor

B. Test equipment required to troubleshoot electronic circuits

C. Service manuals for electronic circuits if available

D. Notepad and pencil

II. Procedure

(NOTE: Your instructor will provide you with an electronic circuit, subassembly, or piece of equipment. The circuitry may contain one or more faults or may be completely operational. Use the following guidelines to isolate problems in the circuitry. Remember that troubleshooting procedures may vary as long as they are logical, systematic applications of sound analysis principles.)

CAUTION

Before performing any maintenance or troubleshooting, follow all safety procedures and isolate equipment as much as possible.

A. Compare actual operation to designed operation

(NOTE: Check the service manual, talk to the operator, and refer to the maintenance history of the equipment to determine expected normal operation.)

B. Determine required inputs

C. Determine subassemblies involved in input

D. Check to see that system is receiving correct inputs

(NOTE: Inputs include electronic, manual, pneumatic, and others. Throughout the troubleshooting procedure, define and record all readings and observations.)

E. Check for proper outputs, beginning at the final output and working toward the first input

F. Determine whether the circuit includes feedback loops

(NOTE: The presence of a feedback loop may indicate that what appears to be faulty input may actually result from faulty output at another point in the system. Likewise, apparently faulty output may result from improper input through the feedback loop.)

JOB SHEET #1

G. Follow specific troubleshooting procedures in the service manual or analyze operation and possible failure modes of subassembly in terms of inputs, outputs, and circuit components.

H. Report your findings to your instructor and discuss repair strategies

I. Put away tools and equipment

(NOTE: Your instructor will have you repeat these procedures on several different types of circuits.)

TROUBLESHOOTING
UNIT I

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with troubleshooting to their definitions.

_____a. A diagram of system blocks, sub-units, or procedures that may be used for troubleshooting

_____b. A circuit that bypasses current around a component or components due to the failure of another component or the accidental bridging of two conductors

_____c. A circuit that has a current flow blocked due to a component failure or broken conductor

_____d. Analog or digital device for voltage, current, and resistance measurements

_____e. A meter that is clamped around a line to determine current in that line

_____f. The injection of a signal within a system to isolate a malfunction to a sub-system

_____g. A device that senses voltage or current or spikes and records the measurements on a strip of paper

_____h. A routine performed to check electronic circuits

_____i. A manual for a specific machine that aids in troubleshooting, ordering parts, assembly, and disassembly of sub-systems

_____j. A partial short that occurs under high voltage conditions

_____k. Map of logical sequence of events that leads to a possible solution to a problem

1. Diagnostics
2. Clamp-on ammeter
3. Flowchart
4. Signal injection
5. Short circuit
6. Leakage
7. Subassembly
8. Open circuit
9. Service manual
10. Multimeter
11. Block diagram
12. Chart recorder

2. State meanings of symbols and abbreviations associated with troubleshooting. Write the correct meaning in the space provided.

a. DVM — ____

TEST

b. ↑ — ____________________

c. ○ — ____________________

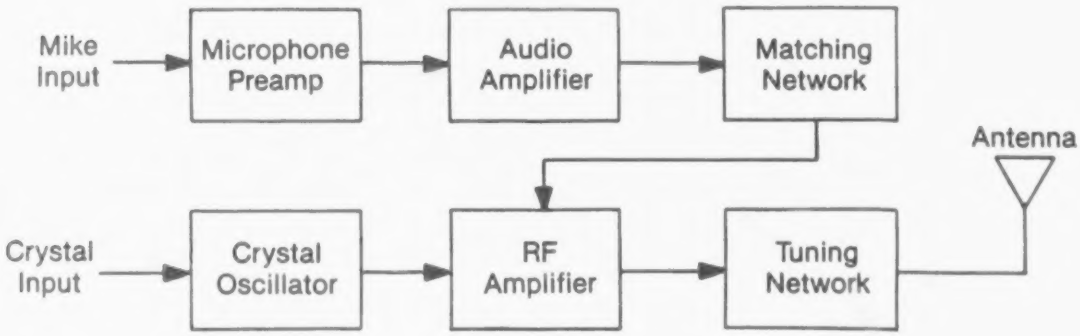
____

d. ▭ — ____________________

e. ◇ — ____________________

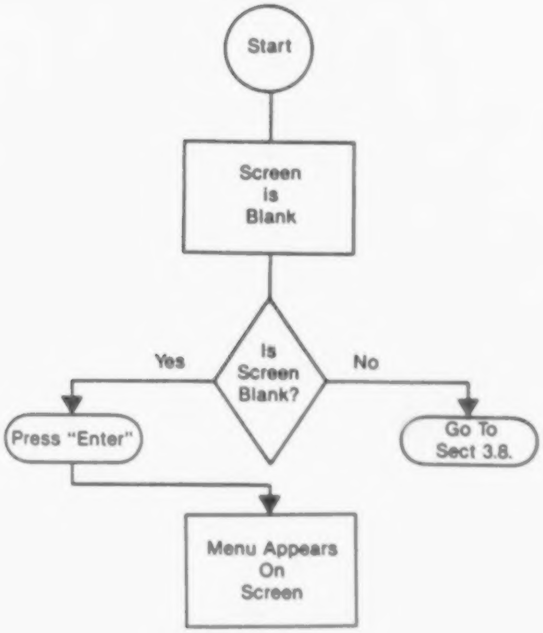
____

3. Label types of block diagrams. Write the correct names in the space provided.

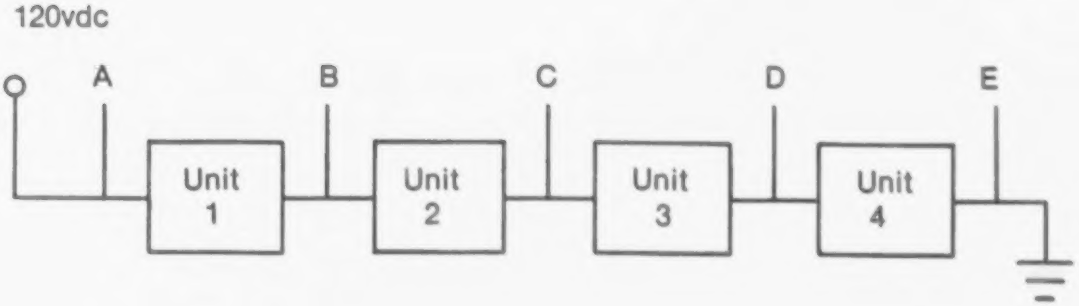

Mike Input
Microphone Preamp
Audio Amplifier
Matching Network
Antenna
Crystal Input
Crystal Oscillator
RF Amplifier
Tuning Network

a. ____________________

TEST


Start
Screen is Blank
Is Screen Blank?
Yes
No
Press "Enter"
Go To Sect 3.8.
Menu Appears On Screen

b. ______________________________


120vdc
A
B
C
D
E
Unit 1
Unit 2
Unit 3
Unit 4

c. ______________________________

TEST

(NOTE: Test questions 4 and 5 represent the assignment sheet and job sheet. They are an important part of this test. If they have not been completed, ask your instructor when you should complete them.)

4. Determine subassemblies that may be at fault by analyzing a block diagram and listed symptoms.

5. Demonstrate the ability to troubleshoot various electronic circuits.

TROUBLESHOOTING
UNIT I

ANSWERS TO TEST

1. a. 11
   b. 5
   c. 8
   d. 10
   e. 2
   f. 4
   g. 12
   h. 1
   i. 9
   j. 7
   k. 6
   l. 3

2. a. Digital voltmeter
   b. Denotes a test point
   c. Flowchart symbols for a manual function or an interruption of an automatic operation
   d. Flowchart symbol for process or function
   e. Flowchart symbol for decision or test results

3. a. Circuit assembly
   b. Flowchart
   c. System network

4. Evaluated to the satisfaction of the instructor.

5. Performance skills evaluated to the satisfaction of the instructor.

TROUBLESHOOTING POWER SUPPLIES
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to use the proper test equipment and proper procedures to troubleshoot power supplies. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with troubleshooting power supplies to their correct definitions.
2. Match abbreviations associated with troubleshooting power supplies to their correct interpretations.
3. Name types of power supplies.
4. Match components to power supply sections in which they are found.
5. Select from a list probable causes for power supply problems.
6. Match control components to their correct methods of operation.
7. Match testing equipment to their correct applications.
8. Arrange in order power supply troubleshooting procedures.
9. Identify power supply circuit functions.
10. Match troubleshooting problems to their correct testing instruments.
11. Demonstrate the ability to
    a. Construct and troubleshoot an AC to DC dual-output power supply.
    b. Construct and troubleshoot an SCR power supply.

TROUBLESHOOTING POWER SUPPLIES
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheet.

   C. Provide students with information, assignment, and job sheets.

   D. Discuss unit and specific objectives.

   E. Discuss information and assignment sheets.

   F. Demonstrate and discuss procedures outlined in job sheets.

   G. Demonstrate troubleshooting procedures through the use of schematic drawings.

   H. Demonstrate the correct procedures for locating test points in troubleshooting; emphasize the importance of troubleshooting in a practical, systematic way.

   I. Give test.

   J. Reteach if necessary.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1 — Typical DC Power Supply Block Diagram

      2. TM #2 — SCRs and Diodes

   E. Assignment sheets

      1. Assignment Sheet #1 — Identify Power Supply Circuit Functions

      2. Assignment Sheet #2 — Match Troubleshooting Problems to Their Correct Testing Instruments

SUGGESTED ACTIVITIES

F. Answers to assignment sheets

G. Job sheets

  1. Job Sheet #1 — Construct and Troubleshoot an AC to DC Dual Output Power Supply

  2. Job Sheet #2 — Construct and Troubleshoot an SCR Power Supply

H. Test

I. Answers to test

III. Unit References

A. Grob, Bernard, and Milton S. Kiver. *Applications of Electronics*, 2nd ed. New York, New York: McGraw-Hill Book Company, 1966.

B. *Industrial Electronics Training Program; Troubleshooting Power Supply, Lesson V.* Barrington, Illinois: TPC Training Systems, Division of Technical Publishing Company, 1978.

C. Shrader, Robert L. *Electronic Communication*, 3rd ed. New York, New York: McGraw-Hill Book Company, 1975.

TROUBLESHOOTING POWER SUPPLIES
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Flux — Magnetic field

B. Electromagnetic field — Magnetic field generated by electrical current

C. Controlled rectifier — Thyristor that can be switched on or off by electrical inputs to control gates

EXAMPLES: Silicon controlled rectifier, silicon unilateral switch

D. Integrated diode bridge — Component containing the equivalent of four diodes arranged in a full-wave bridge

(NOTE: The term *integrated* implies multiple components or their equivalent manufactured as a single component.)

E. Discrete component — Simple, single-function device

F. Thyrector — Device usually comprised of two Zener diodes in series back-to-back, allowing voltage surges to be passed or shunted to protect circuitry or filter our surges

G. Transformer oil — Insulating and heat dissipating liquid used in capacitors or transformers

CAUTION

Old transformers and capacitors may contain PCB fluid which has been found to be an extremely hazardous chemical. This oil substance requires proper handling and disposal in accordance with EPA regulations.

H. Thyristor — Any controlled diode

EXAMPLES: SCRs, Triacs, SUSs

I. Reactor — Term used for an inductor (coil) when applied to large power supplies

J. Dummy load — Artificial load connected to equipment to aid in testing or laboratory troubleshooting; usually a high-wattage resistance network

II. Abbreviations associated with troubleshooting power supplies

A. EPA — Enviromental Protection Agency

B. PCB — Polychlorinated biphenyl

INFORMATION SHEET

C. SUS — Silicon unilateral switch

D. L — Line (input); schematic designator for inductor

E. Pri — Primary winding

F. Sec — Secondary winding

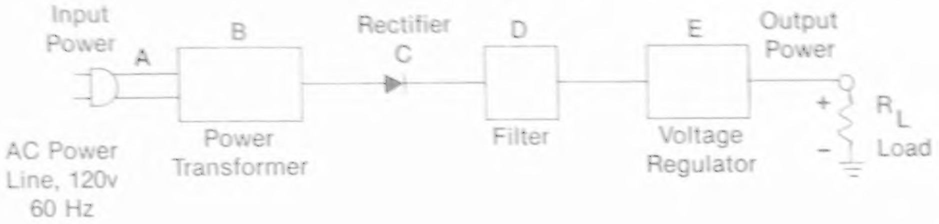
G. CT — Center tap

H. hp — Horsepower

III. Types of power supplies

A. Regulated power supply (Figure 1)

FIGURE 1


Input Power
A
B
Rectifier
C
D
E
Output Power
AC Power Line, 120v 60 Hz
Power Transformer
Filter
Voltage Regulator
+
−
R_L
Load

(NOTE: Voltage regulator stage includes the series regulator, sample and adjust, and shunt regulator.)

B. Unregulated power supply

(NOTE: An unregulated power supply system is like a regulated system except that no voltage regulator is used.)

IV. Power supply sections and their components (Transparency #1; Assignment Sheet #1)

A. Input

1. Power plug and cable
2. Power switch
3. Fuse or breaker
4. Power-on indicator (lamp)

INFORMATION SHEET

B. Transformer

   1. Step-up or step-down

   2. Multiple transformers

   3. Variable inductance

      (NOTE: Variable inductance transformers perform the function of regulation and may have a control winding that electromagnetically diverts flux or a movable core.)

   4. Constant voltage

C. Rectifier

   1. Full or half-wave circuits made up of discrete diodes

   2. Integrated diode bridge

   3. Controlled rectifiers

D. Filter

   1. Capacitors

   2. Inductors

      (NOTE: Inductors are also referred to as *coils, chokes,* or *inductive reactors.*)

   3. Resistors

   4. Thyrectors

E. Series regulator

   1. Power transistor

   2. Multiple transistors

      EXAMPLES: Darlington amplifier, multiple stage amplifier, parallel transistors

F. Shunt regulator

   1. Zener diode

   2. Power transistor

   3. Multiple transistors

INFORMATION SHEET

G. Sample network — Voltage divider network

H. Adjust

  1. Potentiometer

  2. Frequency adjust

     (NOTE: The output of a controlled rectifier power supply may be adjusted and controlled by varying the frequency of the gate inputs.)

I. Reference

  1. Zener diode

  2. Integrated circuit constant voltage or constant current devices

J. Comparator — Dual-input amplifier

EXAMPLES: Differential amplifier, operational amplifier

K. Amplifier (driver) — Single or multiple stages of transistors

V. Power supply problems and probable causes (Transparency #1; Job Sheets #1 and #2)

(NOTE: The most likely components to fail in order from most likely to least likely are fuses, regulator transistors, rectifier diodes, and filter capacitors.)

A. No voltage output

  1. Open fuse

  2. Tripped breaker

  3. Open transformer

  4. Open plug or cable

  5. Faulty component in filter

  6. Open series regulator

  7. Open rectifiers

  8. Open connection

  9. Open switch on unit

INFORMATION SHEET

B. Low voltage output

   1. Defective regulator
   2. Partially shorted transformer
   3. Open ground or neutral connection
   4. Shorted or leaking filter capacitors
   5. Partially open rectifier circuit

      EXAMPLES: Only half-wave rectification resulting in less power output

   6. Improper adjustment
   7. Shorted shunt regulator
   8. Excessive current draw on load

C. Blown fuses

   1. Incorrect fuses
   2. Shorted circuit
   3. Defective regulator
   4. Overloaded circuit

D. No regulation

   1. Defective sample network
   2. Open adjust circuit
   3. Defective reference
   4. Defective comparator
   5. Defective amplifier
   6. Defective regulator

E. High voltage

   1. Improper adjustment
   2. Transformer shorted primary to secondary
   3. Defective regulator

INFORMATION SHEET

F. Excessive ripple

1. Defective filter

2. Partially open rectifier circuit

EXAMPLE: A full-wave bridge with two open diodes would produce only a half-wave output which would not filter as well as a full-wave output

(NOTE: Poorly regulated power supplies and those with minimal filtering actually require a nominal load before filtering is effective.)

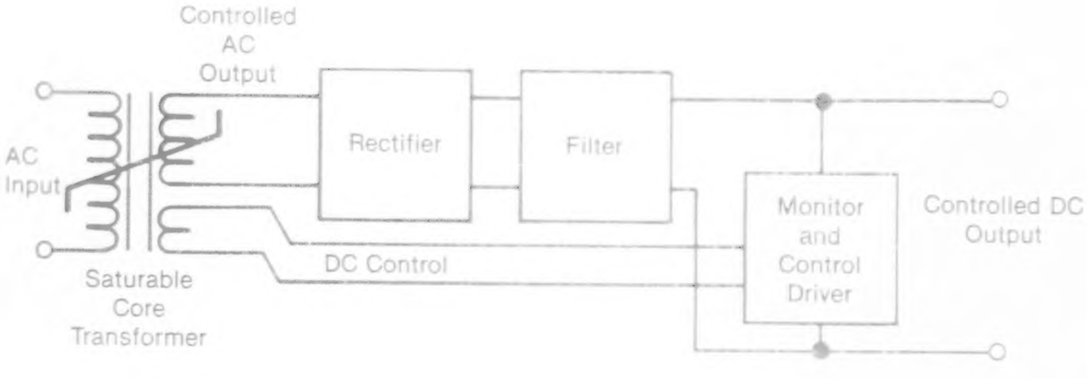
VI. Control components and their methods of operation (Transparency #2; Figures 2-8)

A. Transformer — Saturable core with control winding powered by DC control current

(NOTE: Transformers may also perform as the controlling element by having a movable core or windings. These are called *variable inductance transformers*. A less frequently used method employs multiple taps which are selected automatically by switching devices.)

EXAMPLE:

FIGURE 2


Controlled AC Output
AC Input
Saturable Core Transformer
Rectifier
Filter
DC Control
Monitor and Control Driver
Controlled DC Output

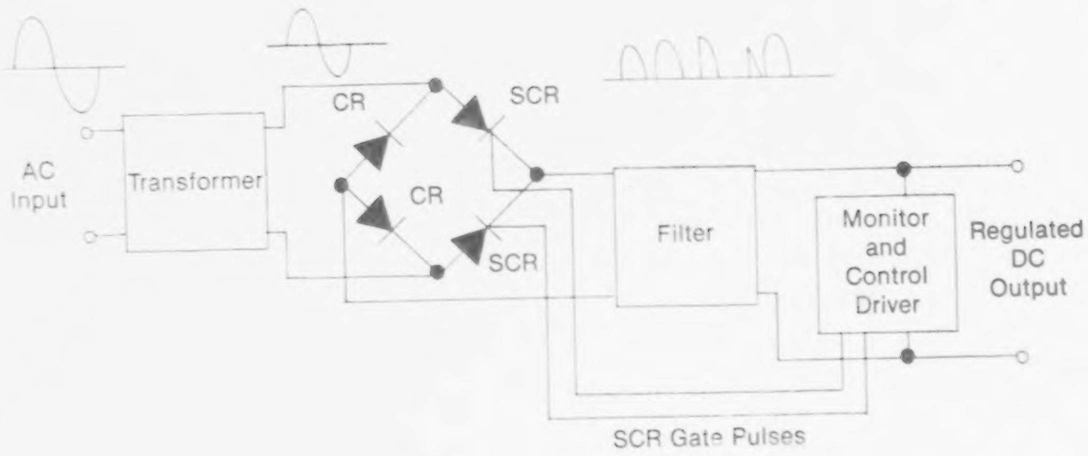
B. SCR — Placed in the rectifier circuitry and controlled by variable frequency impulses

(NOTE: The chopped output of the SCR requires much better filtering to reduce ripple, and is seldom used as a control method for electronic equipment power supplies. More often SCRs are used as DC motor drive power supplies. See Figure 3.)

INFORMATION SHEET

EXAMPLE:

FIGURE 3

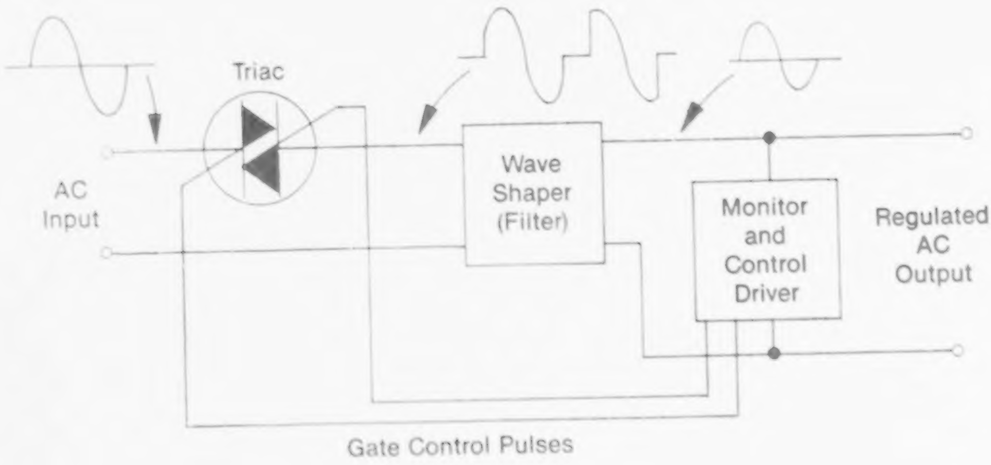

CR
SCR
AC Input
Transformer
CR
SCR
Filter
Monitor and Control Driver
Regulated DC Output
SCR Gate Pulses

C. SUS and Triac — Switch AC on and off to control power output but will not rectify (Figure 4)

(NOTE: The Triac can be switched on and will remain on until the voltage reaches zero. The SUS can be switched on or off.)

EXAMPLE:

FIGURE 4


Triac
AC Input
Wave Shaper (Filter)
Monitor and Control Driver
Regulated AC Output
Gate Control Pulses

INFORMATION SHEET

D. Power transistor — May be placed in series or parallel (shunt) with the load; conductance varies with the amount required to control current (Figures 5 and 6)

EXAMPLES:

FIGURE 5

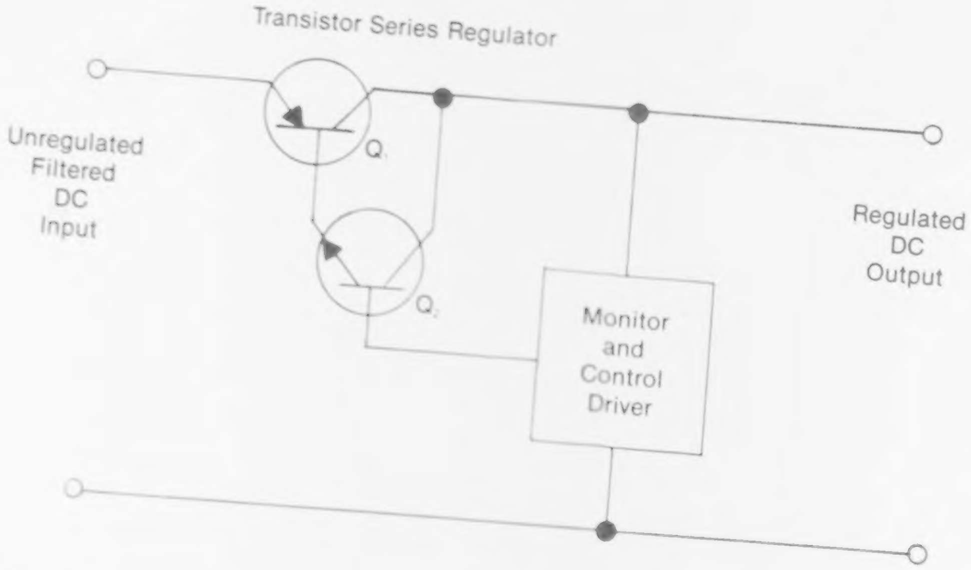
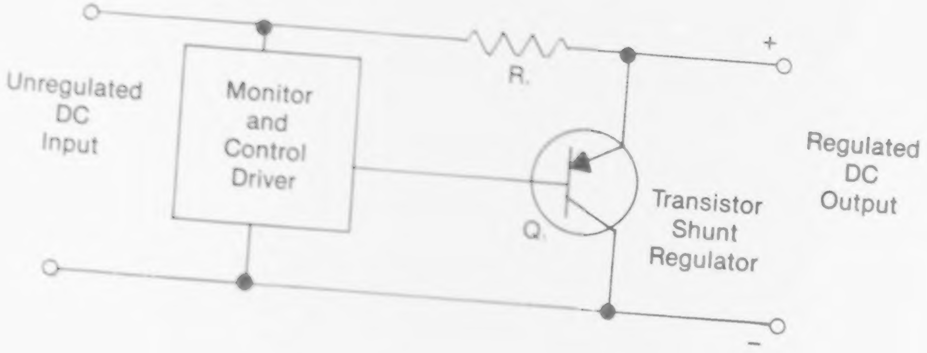

Transistor Series Regulator
Unregulated Filtered DC Input
Q_1
Q_2
Monitor and Control Driver
Regulated DC Output

FIGURE 6

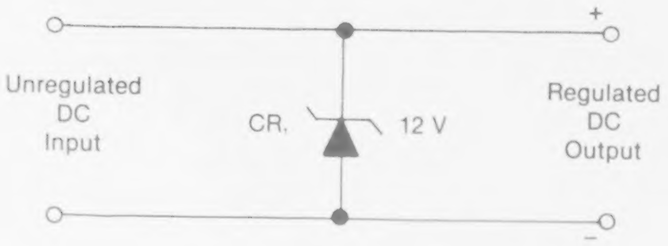

Unregulated DC Input
Monitor and Control Driver
R_1
+
–
Q_1
Transistor Shunt Regulator
Regulated DC Output

INFORMATION SHEET

E. Zener diode — Placed in shunt with load to regulate voltage by conducting current (Figure 7)

(NOTE: Zener diodes operate with current flow in the reverse direction.)

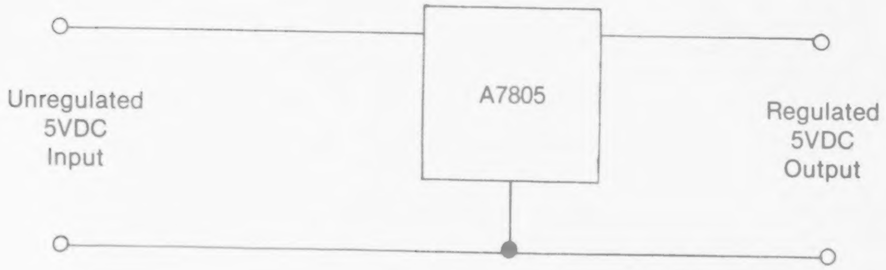
FIGURE 7


+
Unregulated DC Input
CR.
12 V
Regulated DC Output
–

F. Integrated voltage regulators — May be a multiple lead IC such as a DIP, or may appear similar to a transistor or SCR; have built-in monitoring and control functions (Figures 8 and 9)

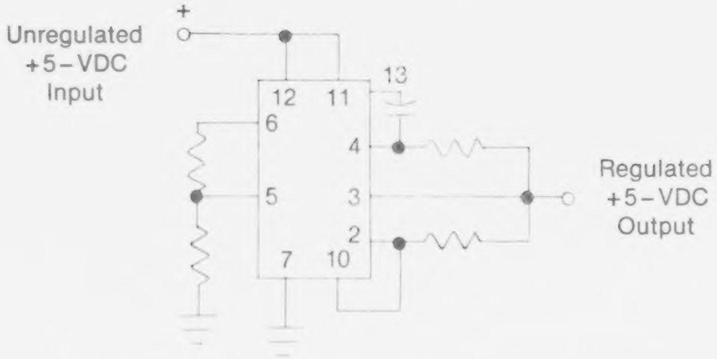
EXAMPLES:

FIGURE 8


Unregulated 5VDC Input
A7805
Regulated 5VDC Output

INFORMATION SHEET

FIGURE 9



VII. Testing equipment and applications (Assignment Sheet #2)

A. Oscilloscope

1. Most useful troubleshooting instrument

(NOTE: The oscilloscope can be used as a voltmeter for AC or DC, or it may be used as a frequency meter or waveform analyzer. With a current probe, the oscilloscope can measure current.)

2. Essential for troubleshooting thyristor circuits

EXAMPLE: A dual-trace scope can be used to monitor gate firing pulses while simultaneously monitoring the voltage waveform output of the thyristor to see that it fires accordingly.

3. Can be used to trace waveforms and thus isolate problems to a section

4. Must be used with power to circuit being analyzed

B. Multimeter

1. Measures voltages, resistance, and low currents

(NOTE: Large amperages may be measured by a clamp-on meter.)

2. May be used to check bipolar transistors and diodes but is not a reliable test for some devices

3. May be used with the power on or off to the circuit being analyzed, depending upon the application

EXAMPLES: Current and voltage checks are made under power; ohms checks must be made with all power off.

INFORMATION SHEET

C. Transistor/diode tester

1. Many types will test bipolar and field-effect transistors, diodes, and thyristors
2. Must be used with the power off to the circuit being analyzed
3. Many types may test components in or out of the circuit

   (NOTE: In-circuit testing under some conditions may show good devices as bad. A final out-of-circuit test should always be used to confirm a defective component.)

D. Capacitor tester

1. Measures capacitance
2. Measures leakage current

E. Insulation tester

1. Tests for insulation breakdown of capacitors and transformers, particularly for ratings over 300 volts
2. Many types measure low-ohm resistances such as contacts, wiring, or transformer windings
3. Must be used with the power off to the circuit being analyzed
4. Will damage low-voltage devices
5. Produces high voltages which could be harmful

VIII. Troubleshooting procedures (Job Sheets 1 and 2)

(NOTE: Sequence of procedures may vary for specific systems and technician preferences. The important point is that a logical, systematic procedure be used.)

A. Use a voltmeter to check for the following

1. Check for proper incoming voltage
2. Check for AC voltage at power supply switch
3. Check for AC voltage at fuse
4. Check for AC voltage at transformer
5. Check for AC voltage at rectifier

INFORMATION SHEET

6. Check for proper DC voltage after rectifier

> **CAUTION**
> Live components may give a severe shock or burn if touched.

B. Circuit tracing during operation

(NOTE: If the power supply must be disconnected from the normal load during troubleshooting, a "dummy load" may be required. A large resistor may be used. For extremely large power supplies, resistive heating elements such as those which heat buildings are often used.)

1. Use a test instrument to trace power from the input to the output
2. Use an oscilloscope to check for
    a. AC input waveform and amplitude
    b. AC output from transformers
    c. Rectification of AC
    d. Gate pulses to thyristors
    e. Thyristor chopped waveforms
    f. Filtering effectiveness
    g. Ripple at the output

C. Visual inspection of component board

1. Check for broken wires or leads
2. Check for cracks in board
3. Check for burned, cracked, melted, or broken components
4. Check for capacitor leaks or broken seals
5. Check for burnt or cracked insulation on inductors, transformers, or conductors

D. Use a clamp-on ammeter to test current flow

1. Check input current to AC transformer
2. Check AC current from rectifier bridge

    (NOTE: Usually high currents indicate a possible short or faulty components.)

INFORMATION SHEET

E. Final defect isolation with power off

1. Test transformers using insulation tester or ohmmeter

   (NOTE: The insulation tester may produce voltages that will damage certain components, particularly solid-state components. It is usually necessary to disconnect the transformer to test it with a Megger. Simple ohmmeter tests for short circuits may not be effective. Often short circuits appear under significantly higher voltages but measure infinite resistance for a low-voltage ohmmeter.)

2. Test capacitors using capacitor tester

3. Test transistors using transistor tester

4. Check diodes with ohmmeter

   (NOTE: If checks A and B do not locate the problem, check C should isolate the problem to a particular section and check D should isolate the defective component.)

F. Suspect component replacement

1. Mark or note wiring before disconnecting to ensure proper replacement

2. Use correct techniques, heat sinks, solder flux to replace component effectively and without damage

   (NOTE: Economical small components are usually replaced with new components once they are removed, whether they are subsequently checked defective or not during out-of-circuit checks. A good technician rarely unsolders a good component; however, because of the low cost of many components, no more than 10 minutes troubleshooting is justified to determine whether they are defective or not.)

G. Final test and repetition of troubleshooting procedure if necessary

1. Use initial checks to verify proper operation

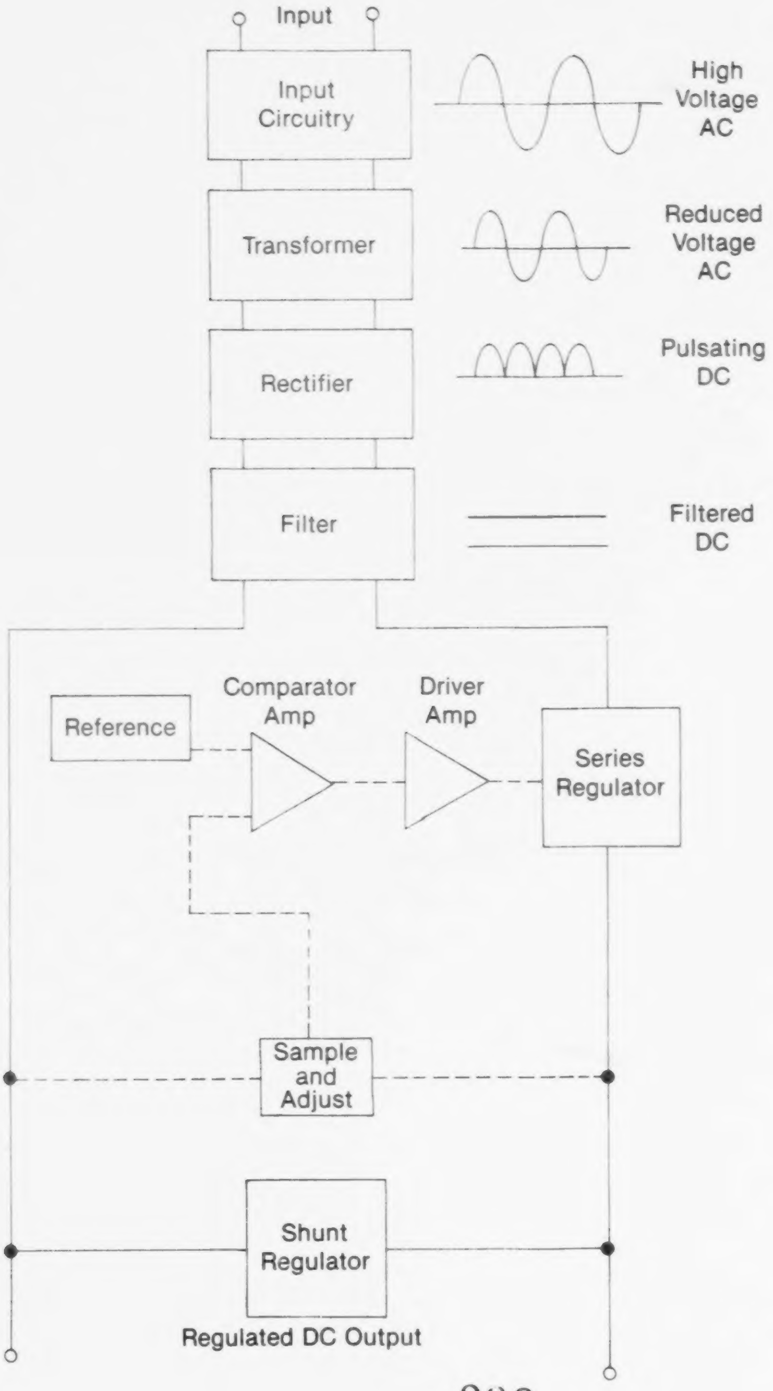
2. Use testing equipment to ensure proper operation

3. Reconnect to normal system load and observe satisfactory operation

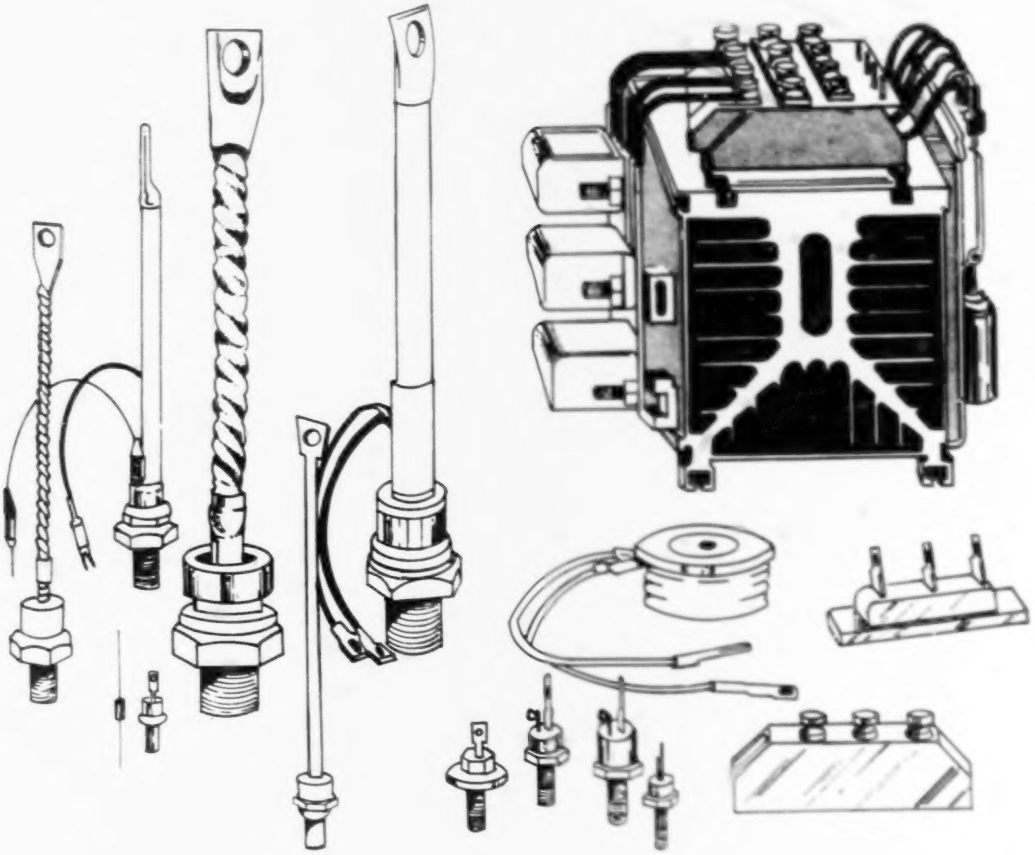
4. Repeat troubleshooting procedures if failures persist

   (NOTE: Equipment often has more than one problem, and the troubleshooting procedure must be followed several times. The initial problem could be external to the power supply, e.g., power source or load, and that problem could result in a secondary failure soon after repair and replacement.)

Typical Regulated DC Power Supply Block Diagram


Input
Input Circuitry
High Voltage AC
Transformer
Reduced Voltage AC
Rectifier
Pulsating DC
Filter
Filtered DC
Reference
Comparator Amp
Driver Amp
Series Regulator
Sample and Adjust
Shunt Regulator
Regulated DC Output

SCRs and Diodes



TROUBLESHOOTING POWER SUPPLIES
UNIT II

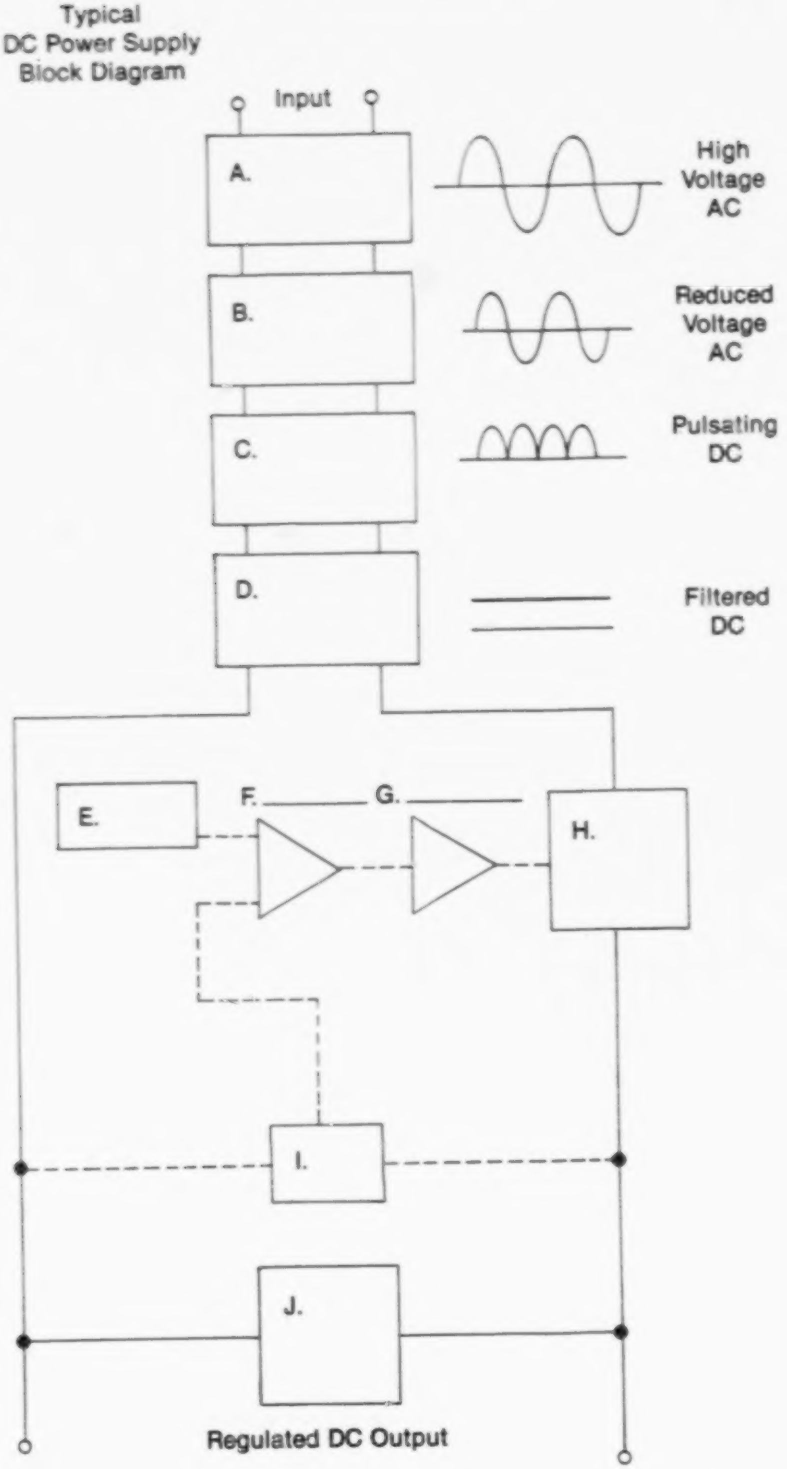
ASSIGNMENT SHEET #1 — IDENTIFY POWER SUPPLY CIRCUIT FUNCTIONS

NAME ______________________________ SCORE ______________

In order to troubleshoot a power supply correctly, a technician must be able to identify the different sections and purposes of a power supply on a schematic diagram.

On the circuit diagram on the following page, identify the specified sections of a power supply.

ASSIGNMENT SHEET #1


Typical
DC Power Supply
Block Diagram
Input
A.
High Voltage AC
B.
Reduced Voltage AC
C.
Pulsating DC
D.
Filtered DC
E.
F. ______
G. ______
H.
I.
J.
Regulated DC Output

ASSIGNMENT SHEET #1

PART B

Beside the letter corresponding to the power supply block diagram describe the function of each section.

A. ______________________________

____

B. ______________________________

____

C. ______________________________

____

D. ______________________________

____

E. ______________________________

____

F. ______________________________

____

G. ______________________________

____

H. ______________________________

____

I. ______________________________

____

J. ______________________________

____

TROUBLESHOOTING POWER SUPPLIES
UNIT II

ASSIGNMENT SHEET #2 — MATCH TROUBLESHOOTING PROBLEMS TO THEIR CORRECT TESTING INSTRUMENTS

NAME ______________________________ SCORE ____________

Effective troubleshooting depends upon the technician's ability to know what to check and how to check it. See how much you have learned from this unit by selecting the most useful testing instrument for each problem listed and placing the correct number in the space provided.

______A. A power supply is overheating, and it is suspected that the load is drawing more current than the power supply is rated; the output current should be measured

______B. The power supply fuse blows as soon as it is turned on; the transister is thought to have a short to ground

______C. The power supply has excessive ripple; the oscilloscope shows full-wave rectification, and the inductors are not defective

______D. An SCR rectifier circuit has been checked with a transister/diode tester which indicated that it is good; the SCR's do not appear to be firing

______E. A three-phase power supply has a low-voltage output, and one of the three input fuses is suspected

______F. The driving amplifier transister of a power supply is suspected to be defective

1. Oscilloscope
2. Multimeter
3. Transister/diode tester
4. Capacitor tester
5. Insulation tester

TROUBLESHOOTING POWER SUPPLIES
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Input circuitry

B. Transformer

C. Rectifier

D. Filter

E. Reference

F. Comparator amplifier

G. Driver amplifier

H. Series regulator

I. Sample and adjust

J. Shunt regulator

Assignment Sheet #1 B

A. Provides incoming power to unit

B. Changes AC to rippled DC

C. Changes AC to rippled DC

D. Reduces ripple effect of DC

E. Provides stable point for comparator

F. Comparator checks voltage to reference

G. Provides signal to series regulator

H. First stage of actual voltage regulation

I. Provides second signal for comparator

J. Final voltage regulation stage

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2

A. 2

B. 2

C. 4

D. 1

E. 2

F. 3

TROUBLESHOOTING POWER SUPPLIES
UNIT II

JOB SHEET #1 — CONSTRUCT AND TROUBLESHOOT AN AC TO DC DUAL-OUTPUT POWER SUPPLY

I. Materials

- A. Fuse and fuse holder, 1/4 A
- B. SPST toggle switch
- C. Indicator lamp, 120 V neon or equivalent (LED with resistor)
- D. Transformer, 120 V, 12V CT
- E. Diode, rectifier, IN4007, 4 each or equivalent or full-wave bridge component
- F. Capacitor, 470 μ, 16 V, 2 each
- G. Zener diode, 6 V, IN4735, 2 each or equivalent
- H. Breadboard
- I. Resistor, 1 w, 51 ohms, 4 each

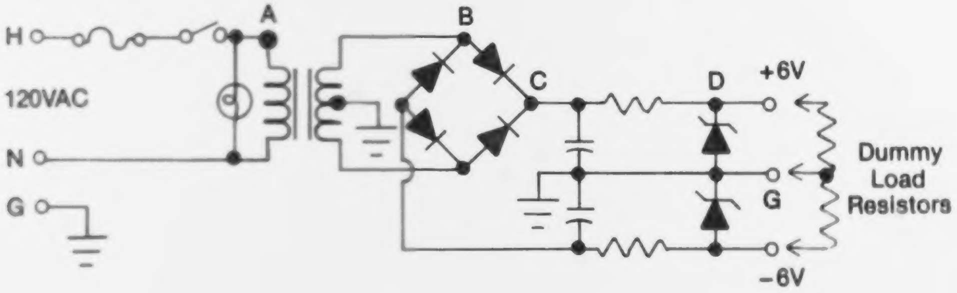
II. Testing equipment

- A. Oscilloscope
- B. Multimeter
- C. Transistor tester
- D. Capacitor tester

III. Procedure

- A. Construct circuit as shown in Figure 10

FIGURE 10



(NOTE: Have the instructor check your circuit.)

JOB SHEET #1

B. With power supply functioning properly, use oscilloscope to trace waveforms at points indicated on the schematic by letters A through D; in the spaces below, note voltages sketch the waveform observed for each point.

1. Point A: peak-to-peak voltages = ______________________________

2. Point B: peak-to-peak voltages = ______________________________

JOB SHEET #1

3. Point C: peak-to-peak voltage = ____________________

zero-to-peak voltage = ____________________

4. Point D: peak-to-peak voltage (ripple) = ____________________

zero-to-peak voltage (DC) = ____________________

C. Remove both capacitors and state the effect observed

____

____

D. Reinstall the capacitors, remove zener diodes, and state the effect observed

____

____

JOB SHEET #1

E. Reinstall zener diodes and remove one rectifier diode; state the effect observed

____

____

F. Disconnect center tap and measure the +6 volt output to ground

Voltage = ______________________________________

(NOTE: Show your observations to the instructor.)

G. Have your instructor insert a troubleshooting problem in your circuit

H. Apply power to circuit and use troubleshooting procedures outlined in this unit to isolate the defective component

Symptoms noted — ________________________________

____

Defects found — _________________________________

____

(NOTE: Have your instructor verify that you have found the defective component and provide you with a replacement.)

I. Put away equipment and materials

TROUBLESHOOTING POWER SUPPLIES
UNIT II

JOB SHEET #2 — CONSTRUCT AND TROUBLESHOOT AN SCR POWER SUPPLY

I. Materials

A. 120 VAC power plug (male) and cable, 3-wire

B. Capacitor, 2 μ, 50 V electrolytic

C. Diode, 1N4007, 2 each

D. Thyrector diode GE-X14

E. Resistor, 2.5 Kohms, 5 W

F. Potentiometer, 500 ohms, 2 W, 2 each

G. Resistor, 1 Kohm, ½ W

H. Fuse, 120 V, 5 A

I. SPST switch

J. SCR, GE-C30B

K. AC plug (receptacle) and cable, 3-wire

L. Universal AC motor, ¼ hp

II. Testing instruments

A. Oscilloscope, dual-trace

B. Multimeter

C. Transistor tester

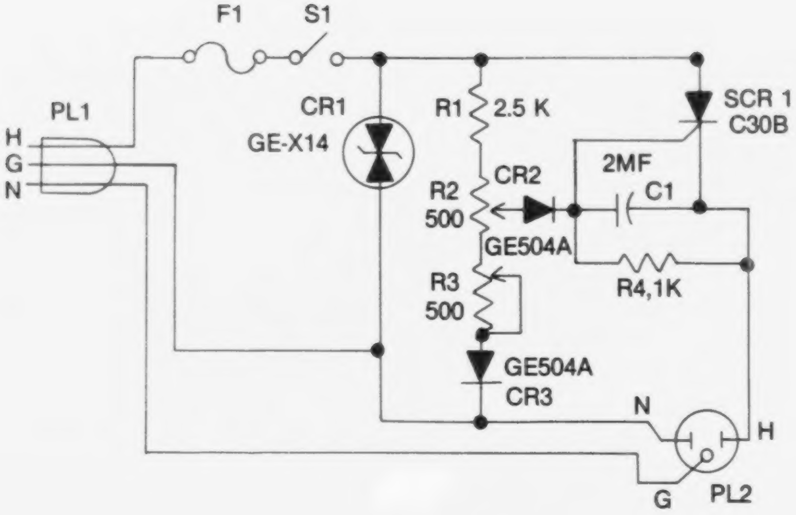
III. Procedure

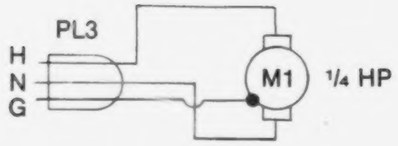
A. Construct circuit as shown in Figure 11, set all potentiometers at midrange

(NOTE: Ask your instructor to check your circuit.)

B. Connect circuit to power

JOB SHEET #2


F1
S1
PL1
H
G
N
CR1
GE-X14
R1
2.5 K
R2
500
CR2
GE504A
R3
500
GE504A
CR3
SCR 1
C30B
2MF
C1
R4,1K
N
H
G
PL2


PL3
H
N
G
M1
¼ HP

JOB SHEET #2

C. Remove CR2 from circuit and state the effect observed

____

____

D. Use oscilloscope while circuit is operating properly, and scope the cathode and gate of SCR1 using the dual-trace

E. With the oscilloscope connected as in step D, slowly adjust R2 down and back up to midrange; state the effect observed

____

____

F. Compare waveform at cathode of SCR1 to motor rpm

____

____

G. Slowly adjust R3 down and back up to midrange; observe changes in the waveforms; state changes observed

____

____

(NOTE: Show your results and comments to the instructor.)

H. Put away tools and equipment

TROUBLESHOOTING POWER SUPPLIES
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with troubleshooting power supplies to their correct definitions. Write the correct numbers in the blanks.

______a. Thyristor that can be switched on or off by electrical inputs to control gates

______b. Simple, single-function device

______c. Insulating and heat dissipating liquid used in capacitors or transformers

______d. Any controlled diode

______e. Term used for an inductor (coil) when applied to large power supplies

______f. Magnetic field generated by electrical current

______g. Component containing the equivalent of four diodes arranged in a full-wave bridge

______h. Device usually comprised of two Zener diodes in series back-to-back, allowing voltage surges to be passed or shunted to protect circuitry or filter out surges

______i. Magnetic field

______j. Artificial load connected to equipment to aid in testing or laboratory troubleshooting; usually a high-wattage resistance network

1. Thyrector
2. Thyristor
3. Dummy load
4. Flux
5. Integrated diode bridge
6. Transformer oil
7. Reactor
8. Discrete component
9. Controlled rectifier
10. Electromagnetic field

2. Match abbreviations associated with troubleshooting power supplies to their correct interpretations. Write the correct numbers in the blanks. Abbreviations and interpretations are continued on next page.

______a. Horsepower

______b. Silicon unilateral switch

______c. Enviromental Protection Agency

1. Pri
2. EPA
3. SCR

TEST

______d. Polychlorinated biphenyl

______e. Line (input); schematic designator for an inductor

______f. Primary winding

______g. Silicon-controlled rectifier

______h. Center tap

______i. Secondary winding

4. L
5. hp
6. Sec
7. CT
8. PCB
9. SUS

3. Name two types of power supplies. Write the names in the spaces provided.

a. ______________________________

b. ______________________________

4. Match components to power supply sections in which they are found. Write the correct numbers in the blanks.

______a. Full or half-wave discrete diodes, integrated diode bridge, controlled rectifiers

______b. Step-up or step-down, multiple transformers, variable inductance

______c. Capacitors, inductors, thyrectors

______d. Zener diode, power transistor, multiple transistors

______e. Power plug and cable, power switch fuse or breaker, power-on indicator (lamp)

______f. Dual-input amplifier

______g. Potentiometer, frequency adjust

______h. Zener diode, integrated circuit constant voltage or constant current device

______i. Voltage divider network

______j. Power transmission, multiple transistors

______k. Single or multiple stages of transformers

1. Input
2. Rectifier
3. Series regulator
4. Sample network
5. Transformer
6. Amplifier (driver)
7. Adjust
8. Shunt regulator
9. Filter
10. Comparator
11. Reference

TEST

5. Select from the following lists probable causes for power supply problems. Write an "X" in the blank before each correct answer.

a. No voltage output

_____1) Incorrect fuse

_____2) Open fuse

_____3) Improper adjustment

_____4) Open connection

_____5) Open series regulator

_____6) Defective regulator

_____7) Partially shorted transformer

_____8) Tripped breaker

_____9) Open transformer

_____10) Defective amplifier

_____11) Open plug or cable

_____12) Open rectifiers

_____13) Faulty component in filter

b. Low voltage output

_____1) Shorted or leaking filter capacitors

_____2) Incorrect fuse

_____3) Open fuse

_____4) Partially open rectifier circuit

_____5) Open ground or neutral connection

_____6) Open plug or cable

_____7) Defective regulator

_____8) Partially shorted transformer

TEST

_____9) Tripped breaker

_____10) Open series regulator

_____11) Improper adjustment

_____12) Defective reference

_____13) Shorted shunt regulator

c. Blown fuses

_____1) Partially open rectifier circuit

_____2) Incorrect fuses

_____3) Improper adjustment

_____4) Shorted circuit

_____5) Open transformer

_____6) Defective regulator

_____7) Open rectifiers

d. No regulation

_____1) Defective regulator

_____2) Open fuse

_____3) Defective sample network

_____4) Open adjust circuit

_____5) Tripped breaker

_____6) Defective reference

_____7) Defective comparator

_____8) Partially open rectifier circuit

_____9) Defective amplifier

_____10) Improper adjustment

_____11) Open series regulator

_____12) Tripped breaker

TEST

e. High voltage

______1) Tripped breaker

______2) Open ground or neutral connection

______3) Improper adjustment

______4) Transformer shorted primary to secondary

______5) Open plug or cable

______6) Defective regulator

f. Excessive ripple

______1) Partially open rectifier circuit

______2) Partially shorted transformer

______3) Defective filter

______4) Defective regulator

6. Match control components to their correct methods of operation. Write the correct numbers in the blanks.

______a. Switch AC on and off to control power output but will not rectify

______b. May be a multiple lead IC such as a DIP, or may appear similar to a transistor or SCR; have built-in monitor and control functions

______c. Saturable core with control winding powered by DC control current

______d. Placed in shunt with the load to regulate voltage by conducting current

______e. Placed in rectifier circuitry and controlled by variable frequency impulses

______f. May be placed in series or parallel (shunt) with load; conductance varies with the amount required to control current

1. Transformer
2. SCR
3. SUS and Triac
4. Power transistor
5. Zener diode
6. Integrated voltage regulators

TEST

7. Match testing equipment to its correct application. Write the correct numbers in the blanks. A number may be used more than once. Applications are continued on next page.

_____a. Many types will test bipolar and field-effect transistors, diodes, and thyristors

_____b. Measures voltages, resistance, and low currents

_____c. Essential for troubleshooting thyristor circuits

_____d. Measures capacitance

_____e. May damage low voltage devices

_____f. May be used to check bipolar transistors and diodes but is not reliable test for some devices

_____g. Many types may test components in or out of circuit

_____h. Can be used for trace waveforms and thus isolate problems to a section

_____i. May be used with power on or off to circuit being analyzed, depending upon the application

_____j. Measures leakage current and insulation breakdown

_____k. Must be used with power off to circuit being analyzed

_____l. Produces high voltages which could be harmful or fatal

_____m. Most useful troubleshooting instrument

_____n. Must be used with power on to circuit being analyzed

_____o. Many types measure low-ohm resistances such as contacts, wiring, or transformer windings

_____p. Tests for insulation breakdown of capacitors and transformers, particularly for ratings over 300 volts

1. Oscilloscope
2. Multimeter
3. Transistor/diode tester
4. Capacitor tester
5. Insulation tester (Megger)

TEST

8. Arrange in order power supply troubleshooting procedures. Write a "1" before the first step, a "2" before the second step, and so on.

______a. Final defect isolation with power off

______b. Use a clamp-on ammeter to test current flow

______c. Use a voltmeter to check for proper incoming voltage; AC voltage at power supply switch, fuse, transformer, and rectifier; and proper DC voltage after rectifier

______d. Suspect component replacement

______e. Final test and repetition of troubleshooting procedures

______f. Circuit tracing during operation

______g. Visual inspection of component board

(NOTE: Test questions 9-11 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

9. Identify power supply circuit functions.

10. Match troubleshooting problems to their correct testing instruments.

11. Demonstrate the ability to

    a. Construct and troubleshoot an AC to DC dual-output power supply.

    b. Construct and troubleshoot an SCR power supply.

TROUBLESHOOTING POWER SUPPLIES
UNIT II

ANSWERS TO TEST

1. a. 9
   b. 8
   c. 6
   d. 2
   e. 7
   f. 10
   g. 5
   h. 1
   i. 4
   j. 3

2. a. 5
   b. 9
   c. 2
   d. 8
   e. 4
   f. 1
   g. 3
   h. 6

3. a. Regulated
   b. Unregulated

4. a. 2
   b. 5
   c. 9
   d. 8
   e. 1
   f.
   g. 7
   h. 11
   i. 4
   j. 3
   k. 6

5. a. 2, 4, 5, 8, 9, 11, 12, 13
   b. 1, 4, 5, 7, 8, 11, 13
   c. 2, 4, 6
   d. 1, 3, 4, 6, 7, 9
   e. 3, 4, 6
   f. 1, 3

6. a. 3
   b. 6
   c. 1
   d. 5
   e. 2
   f. 4

7. a. 3
   b. 2
   c. 1
   d. 4
   e. 5
   f. 2
   g. 3
   h. 1
   i. 2
   j. 4
   k. 3 or 5
   l. 5
   m. 1
   n. 1
   o. 5
   p. 5

ANSWERS TO TEST

8. a. 5
   b. 4
   c. 1
   d. 6
   e. 7
   f. 2
   g. 3

9. Evaluated to the satisfaction of the instructor

10. Evaluated to the satisfaction of the instructor

11. Performance skills evaluated to the satisfaction of the instructor